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Davis, CA

Second Report

National Spray Model Advisory Committee

FPM 91-10
November 15, 1991

Pesticides used improperly can be injurious to human beings, animals, and plants. Follow the directions and heed all precautions on labels. Store pesticides in original containers under lock and key—out of the reach of children and animals—and away from food and feed.

Apply pesticides so that they do not endanger humans, livestock, crops, beneficial insects, fish, and wildlife. Do not apply pesticides where there is danger of drift when honey bees or other pollinating insects are visiting plants, or in ways that may contaminate water or leave illegal residues.

Avoid prolonged inhalation of pesticide sprays or dusts; wear protective clothing and equipment, if specified on the label.

If your hands become contaminated with a pesticide, do not eat or drink until you have washed. In case a pesticide is swallowed or gets in the eyes, follow the first aid treatment given on the label, and get prompt medical attention. If a pesticide is spilled on your skin or clothing, remove clothing immediately and wash skin thoroughly.

NOTE: Some States have restrictions on the use of certain pesticides. Check your State and local regulations. Also, because registrations of pesticides are under constant review by the U.S Environmental Protection Agency, consult your local forest pathologist, county agriculture agent, or State extension specialist to be sure the intended use is still registered.

FPM 91-10
NOVEMBER 15, 1991

SECOND REPORT

NATIONAL SPRAY MODEL ADVISORY COMMITTEE

Prepared by:

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Chairperson

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SECOND REPORT

National Spray Model
Advisory Committee

Notes of the Blacksburg, VA
Meeting, September 12-13, 1991

November 15, 1991

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I. INTRODUCTION

The meeting was held at the Blacksburg Marriott Hotel, Blacksburg, Virginia, September 12-13, 1991. The meeting was preceded by the fourth meeting of the National Steering Committee for Managing Gypsy Moth and Eastern Defoliators. A single meeting place provided for economies as some attendees participate in both committees.

A. Attendees:

Linda Abbott	USDA-APHIS-BBEP (Hyattsville, MD)
Duan Baozhong	Pennsylvania State University (University Park, PA)
Terry Biery*	USAF Reserve (Rickenbacker, OH)
Scott Cameron*	Texas Forest Service (Lufkin, TX)
John Craig	Labat-Anderson, Inc. (Arlington, VA)
Robert Ekblad*	USDA Forest Service (Retired) (Missoula, MT)
Dave Esterly*	E.I. DuPont and Spray Drift Task Force (Newark, DE)
Harold Flake*	USDA Forest Service (R-8) (Atlanta, GA)
Bruce Grim*	U.S. Army Dugway Proving Ground (Dugway, UT)
Ellis Huddleston*	New Mexico State University (Las Cruces, NM)
Steve Knight	USDA-APHIS-PDQ (Hyattsville, MD)
Karl Mierzejewski	Pennsylvania State University (University Park, PA)
Jim Rafferty*	U.S. Army Dugway Proving Ground (Dugway, UT)

Dick Reardon*	USDA Forest Service (NA) (Morgantown, WV)
Brian Richardson*	Forest Research Institute (Rotorua, New Zealand)
Dave Rising*	Missoula Technology Development Center (Missoula, MT)
Doug Sommerville	US Army CRDEC (Aberdeen, MD)
Pat Skyler*	USDA Forest Service (WO/FPM) (Davis, CA)
Milt Teske	Continuum Dynamics, Inc. (Princeton, NJ)
Dave Valcore*	Dow Elanco Spray Drift Task Force (Indianapolis, IN)
Dave Whiteman*	Battelle NW Labs (Richland, WA)
Jack Barry* (Chairperson)	USDA Forest Service (WO/FPM) (Davis, CA)

Notes: Asterisk (*) indicates committee member
Milt Teske is an ad hoc member

B. Purpose of Committee/Meeting

The purpose of the committee is to identify needs related to the FSCBG and AGDISP pesticide spray computer models, and list priorities related to development, enhancement, evaluation, validation, training and technology transfer. Identified needs are sent to the USDA Forest Service (Forest Service), Director of Forest Pest Management for program and funding considerations. Equally the recommendations are also used by other public and private

organizations for consideration in managing their pesticide application R&D program. The Blacksburg meeting, therefore, provided a forum for constituents to express their needs and to state where emphasis should be placed in advancing the pesticide application models.

C. Future Direction

The Forest Service, in partnership with the U.S. Army, has brought the pesticide application models to their current operational status. The interest and need for the models have expanded to other Federal, State, academia, industry, and to international users. It is the Forest Service's position that further development and enhancements of the model should be shared by the entity that has the specific need - whether it be model validation, evaluation, or enhancement. The Model User Group, established by the Forest Service through a memorandum of understanding with Continuum Dynamics, Inc., and the National Spray Model Advisory Committee are appropriate coordination points for model work of the nature described above.

II. DISCUSSION

The discussion as presented herein are remarks by attendees and/or a summary of their work, statements, and concerns. Some attendees provided a written summary which is enclosed in the Appendices. Likewise some non-attending committee members submitted written summaries which also are enclosed in the Appendices.

A. Attendees Remarks and Reports

Linda Abbott

- APHIS employee working for Environmental Analysis and Documentation Branch, involved with the Mediterranean fruit fly EIS and effects of malathion on non-target species. Plans to take FSCBG training to help on her job assignments.

Jack Barry

- Noted that atomization and evaporation are critical to managing drift.

- Need to push forward in developing or adapting models that predict evaporation. The U.S. Army has models for evaporation of multi-component fluids and these could be used in conjunction with measured evaporation data.

- Bill Steinke, University of California, has Forest Service funds to evaluate feasibility of modeling atomization based upon an empirical approach.

- Forest Service and U.S. Army conducted an off-site movement study this spring in conjunction with the Utah gypsy moth eradication project. Study objectives were to quantify off-site drift; evaluate different types of drift samples; and to compare field observations to model predictions.

- Committee needs to study and develop mechanisms to get models accepted in the legal system.

- Meeting scheduled for October 23, 1991 at Salt Lake City to brainstorm ideas and develop strategy on how to approach and convince EPA to accept model data for registration purposes. The meeting, hosted by U.S. Army colleagues, will be attended by Jim

Rafferty, Jim Bowers, Bruce Grim, Milt Teske, Dave Esterly, Dave Valcore and Roger Drewes.

. University of California, Davis, CA (UCD), Department of Agricultural Engineering, has a wind tunnel for characterizing spray from atomizers. I believe this was the first such tunnel for this use in the U.S. During initial set-up and check-out, Professor Yates conducted a series of tests to calibrate the tunnel and its supporting instrumentation. This was published in the Transactions of the American Society of Agricultural Engineering. Now other wind tunnels exist. To compare results amongst the various tunnels would be nearly impossible and there are questions on how the other tunnel systems have been calibrated. Tunnel design, instrumentation, and operating procedures all differ to some extent. I will contact ASAE through Bill Steinke and recommend that ASAE consider developing standards for testing atomizers in wind tunnels.

. Those wanting results of the Program Wind AMADEUS study should contact Ron Cionco directly (505) 678-5210. The study involved studying transport of a smoke plume in complex terrain.

. The Forest Service has no interest at this time in enhancing FSCBG to diffuse spray within forest canopies. We do, however, need to make some assumptions on how much material (mass and drops) remain in the canopy and also ventilates or exits the canopy. These assumptions or constants will vary depending upon forest characteristics and other factors.

Terry Biery

. FSCBG is a good tool to educate the public on spraying and to develop public acceptance. The model is helpful to sort-out real vs perceived risks.

- Consider including an urban environment in FSCBG model.

- Need the model to give us (quickly) in the field (using actual weather conditions) the following:

  a. The downwind first point of deposition.

  b. The downwind point of a previously determined deposition/concentration cut-off of environmentally hazardous drift.

- Other Items of Group Interest:

  a. We will be teaching the DOD Aerial Dispersal of Pesticide Certification Course at our facility in Columbus, OH on 12-15 October 1991. If you have anyone interested in attending let me know.

  b. If the Forest Service needs to do additional validation studies with a large aircraft like the C-130 for the model, please let me know; I'll work your request through our command structure.

  c. I want to thank Jack Barry, Bob Ekblad, Bruce Grim, Jim Rafferty and Milt Teske for their assistance when we were preparing a contingency plan for spraying insect vectors during Desert Storm. Although the war concluded so rapidly that we were not required to spray, we got excellent information from the model on how to approach controlling insect vectors with a C-130 aircraft aerial spray system in an extreme desert environment.

d. We need to use the model to assist aerial spray monitors in making go or no-go spray decision and justifying it with a model output using weather conditions forecasted.

Scott Cameron

- Primary interest is pest management in southern pine seed orchards.

- Will be using FSCBG to look at drift from seed orchard spraying to avoid sensitive areas.

- Interested in data on optimum drop size.

- Conducting a study to investigate spray deposition in coniferous orchards and using FSCBG to calibrate a ground based aerial spray simulator.

- Wants "rule of thumb" manual for making spray decisions.

- Need to adapt FSCBG to ground spray application

Bob Ekblad

- Noted that this committee seems to be moving more toward using the models vs solely being concerned about validation.

- Reported that the U.S. Army (DPG) is cooperating with the Forest Service and the Spray Drift Task Force in conducting a series of tank-mix evaporation studies.

- The U.S. Army contractor is Southern Research Institute, Birmingham, Alabama. Test solutions will be water, water plus a polymer, and soybean oil.

- U.S. Government objective is to initiate the evaporation activity and turn over the technology to the private sector.

- Remind the committee that Colorado State University conducted evaporation studies in 1982 on 13 different tank-mixes. The MTDC report titled <u>Determination of Evaporation Rates for Pesticide Droplets</u> (1984) is available from MTDC or Jack Barry.

- R-6 priority for evaporation determination of tank-mixes is listed by priority: Foray 48B; Thuricide 48LV: Dipel 8AF; and Dipel 8L.

- Bob, as a Forest Service volunteer, will continue with the evaporation project until it's completed.

- VALMET (Complex Terrain Model) - 1st version of it should be a documented, usable model by spring (1992). Needs validation testing with FSCBG and AGDISP. Will need a field test to validate the complex terrain model.

<u>Dave Esterly</u>

- Need model to be accepted by academia, regulators, and legal community.

- Need to know what size particles drift. SDTF hopes to have some answers in 6-9 weeks.

- Use of models within the legal arena came up at an EPA meeting. Need to use models in pesticide registration process. SDTF does not know how to approach EPA on this issue.

- Stated in response to Duan Baozhong that funding model validation, etc. is not a problem, what is a problem is getting EPA to accept model output for registration.

Harold Flake

- Interested in forest stand structure, stand profile, etc. Demonstrated his research on space occupancy concept as possible use in FSCBG. Stated that forest inventory data bases exist that could be accessible by computers.

- Need method to estimate total vegetative surface area of treatment blocks.

Bruce Grim

- U.S. Army conducted a canopy penetration study in conjunction with the 1990 & 1991 R-4 gypsy moth eradication projects. Field observations will be compared to model predictions.

- On future studies of spray drift in mountainous terrain we might want to sample the spray in the cold air core above the surface as described by Dave Whiteman.

Ellis Huddleston

- Has a student who is comparing the drop size spectrum using the Malvern and PMS practical measuring systems.

- Has data that might be helpful in evaluating FSCBG.

- Bob Sanderson is now on a tenure-track at New Mexico State University (NMSU).

- ESCOP (Experiment Station Committee on Policy) conference might be held at NMSU in 1992. Agriculture Research Institute workshop on application technology also might be held at NMSU in 1992.

- Bob Sanderson is planning a "Cranfield" type course at NMSU for October 1992. This hands-on session for 20 students will involve academia, industry, and government instructors and students.

- NMSU is working with Bob Mickel (Canada) to instrument NMSU's experimental spray aircraft.

- FSCBG can be used to establish criteria for shutting-down spraying.

<u>Steve Knight</u>

- APHIS has strong interest in FSCBG and is attending this meeting to hear about model sensitivity and validation studies. Other FSCBG interests include those related to: spraying of urban environments; NEPA; litigation; mitigation; preparation of EIS's; negotiating on endangered and threatened species; and optimum timing of spray.

- Will be seeing increasing APHIS interest in FSCBG and AGDISP.

<u>Mike McManus</u>

- Need "rule of thumb" for recommending optimum spray conditions for any given set of conditions that might be experienced in forest spraying.

- His research project involves developing microbial pesticides.

- Sees FSCBG becoming increasingly more important in its use to predict drift.

Karl Mierzejewski

- Completed NAPIAP funded accountability study with Dimilin WP. Samples have not been analyzed.

- Reported on preliminary results of Dave Miller's research on FSCBG in forest canopy.

Jim Rafferty

- Has been reviewing the canopy penetration code of FSCBG. Plans to conduct FSCBG sensitivity studies.

- LI-COR, an instrument that measures light penetration into vegetative canopies, shows great promise as a method to characterize canopies. This could replace the need to make field measurements (or guesses) of foliage density, stems per acre, and tree envelope for input to FSCBG.

- Next step is to provide Milt Teske with data so foliage fraction can be incorporated in FSCBG.

Dick Reardon

- Sub-Committee to Coordinate Spray Model Applications in Eastern Broad-leaved Forests

    - Letter sent to potential members on Jan. 18, 1991 and all agreed to participate: Jim Rafferty and Bruce Grim, Dave

Miller, Milton Teske, Karl Mierzejewski and Duan Baozhong, Bob Mickle and Dave Valcore

- Initial meeting scheduled for April 1991

- No progress as sub-committee but individual projects conducted.

• FSCBG/AGDISP Research and Methods Improvement Activities in Eastern US

  - Funding ($30,000.) provided to Dave Miller (U of CT) via cooperative agreement 42-579 to gather micrometeorological data during a simulated suppression project and to continue FSCBG sensitivity analysis.

  - Conducted cooperative project with U of CT (Miller), NEFAAT (Yendol/Mierzejewski/Pendergast), APHIS (Roland/McLane) to determine spray accountability for an aerial application of Dimilin to a broad-leaved forest.

  - Conduct airport trials to verify DC-3 swath widths as compared to those predicted in 1990 FPM Report <u>Swath Width Evaluation</u>. Week of September 23, 1991 at K&K Aircraft, Bridgewater, VA.

  - Incorporate AGDISP version into SWATH KIT.

<u>1992 Needs</u>

• Conduct drift component of the Dimilin accountability project.

• Continue FSCBG model sensitivity analyses for eastern broad-leaved forests.

- Acquire canopy architecture for eastern deciduous forests for input and enhancement of FSCBG.

- Conduct airport trials to verify randomly selected AGDISP swath width predictions reported in 1990 FPM Report Swath Width Evaluation.

Other

- Expressed concern about potential differences in results among different wind tunnels. Perhaps there is a need for a round robin study.

- Expressed concern over lack of protocols in determining spread factors.

- Concerned about evaporation of Dimilin tank-mixes. Yendol funded to do a drift study.

Brian Richardson

- Has been working on FSCBG and conducting field tests the past 12 months. New Zealand's primary interest is predicting drift of herbicide spray. Major activities have been validation and sensitivity studies. He found no major surprises as a result of the sensitivity work. Used Rotorods, corrected for wind velocity, as samplers for his drift studies. Has observed good agreement between FSCBG predictions and field data near field but less agreement downfield.

- Planning an FSCBG training session in New Zealand during late May early June 1992, with 25 students from New Zealand and Australia. Requests assistance from Forest Service and CDI.

- See Brian's report in Appendix C.

Dave Rising

- Tony Jasumback, MTDC, (406) 329-3900, is a national specialist on Geographical positioning systems (GPS). He is available for consultation.

Pat Skyler

- Prepared and distributed the second FSCBG/AGDISP Model Technology Transfer Letter. It was sent to User Group and others who have expressed interest in the spray models.

- Utah 1991 Gypsy Moth - will be working with Milt Teske analyzing data from the off-target movement study.

- Made FSCBG prediction in support of R-4 gypsy moth project. Modeled a Bell 206 with 4 Beecomist to predict swath width and downwind drift.

- Ran AGDISP model for R-8 to determine swath width for an AT-802 aircraft.

- Trained Bonita Mendenhall, an ARS employee who works for Al Womac, in how to run FSCBG.

- Will assist Milt Teske as assistant instructor at the November FSCBG 4.0 training in Las Cruces, NM.

- Updated and finalized the drop size report to incorporate virus tank-mix wind tunnel tests that UCD completed for Region 6 and AIPM.

- Have started cataloging FPM/Davis pesticide application and safety library that includes all of the model references and 100's of related references. References will be placed in a computer data base and also published.

Doug Sommerville

- Interested in CRDEC cooperation with the committee in spread factor work.

- CRDEC likes AGDISP model, has not worked with FSCBG.

- Doing ground sprayer work and would welcome working with the Forest Service on ground sprayers.

- Needs data, as does Forest Service, on velocity of drops generated by ground sprayers.

- Volunteered to do study comparing Kromekote to Teflon sheet samplers.

- See Doug's letter in Appendix C.

Milt Teske

- Gave a briefing on status of FSCBG and AGDISP. FSCBG 4.0 is out for review.

- Over the last 20 years the USDA Forest Service and the U.S. Army have been developing computer models to predict the deposition and dispersion of aerially released spray. Their approach has been:

Develop predictive tools that model material fate in the atmosphere.

Fashion computer models that run quickly and accurately on personal computers.

Validate these models against field data.

Train in the operation of these models.

Support the improvement and distribution of these models to the user community.

- Jack Barry also wants the FSCBG to predict total accountancy - where is the spray material at any point in time.

- See Milt's report in Appendix C.

<u>Dave Valcore</u>

- Spray Drift Task Force

  Status: Joint venture of 26 companies to supply drift data to the EPA for all types of applications to include: aerial, ground, air blast, chemigation.

  Goals: Use generic physical property measurements to predict atomization results, and use spray size distribution and evaporation rate as correlation to downwind drift; preferably with a predictive theoretical model.

  Progress: Atomization study completed for range finding matrix of physical property limits. Field test conducted for limited test solutions with aerial, ground and airblast applications for

low-high rates/conditions. Commissioned sensitivity studies of major variables of FSCBG/AGDISP and the Dow Elanco Drift Model.

- Conducted tests in Mississippi in 1991; data will be compared to model predictions.

- Need standards for conducting wind tunnel tests - and round robin among various wind tunnels.

- See Dave's report in Appendix C.

Dave Whiteman

- Meteorology in complex terrain areas differs from meteorology over flat terrain areas. Over complex terrain, thermally driven circulations are generated when boundary layers form over inclined surfaces. The meteorology during the morning transition period, when spraying is usually conducted, involves multiple interacting layers in the wind and temperature structure. Additional complications come from specific topographic effects and the degree of coupling between the winds within and above the complex terrain area. Forest pesticide spraying in mountainous areas must be cognizant of these meteorological differences.

- Existing FSCBG and AGDISP models were not designed to predict dispersion over complex terrain areas, and will need modification to handle complex terrain situations properly.

- Several initial modeling approaches are underway to improve complex terrain modeling performance. First, a solar shading algorithm has been combined with USGS digital elevation models to predict isochrones of sunrise time in specific valleys at different times of the year. Such isochrones should prove useful

in future planning of aerial spraying campaigns. Second, modifications are presently being made to a phenomenological model originally developed for the EPA, called VALMET to optimize it for predicting drift in confined valley topography. CDI has demonstrated that results from such a model could be output using the AGDISP plotting routines. Also, the modified VALMET model will take advantage of AGDISP calculations for determining the non-deposited fraction of the sprayed material.

Recommendations

- A manual describing complex terrain meteorological phenomena and their effect on aerial spraying operations should be commissioned. This manual should provide useful rules of thumb, simple algorithms for making relevant meteorological calculations, nomograms, tables, etc. that would be useful for the planning and conduct of aerial spraying operations.

- Forest Service should implement, in-house, a technique recently demonstrated by Battelle to use digital elevation models and solar shading algorithms to aid in the planning of future spraying campaigns in complex terrain areas.

- The existing EPA model, VALMET, should be modified and optimized for aerial spraying in confined valley situations. Initial work is presently under way.

- New Doppler mini-sodar and aircraft navigation using Geographical Positioning System (GPS) technologies should be investigated for routine incorporation into spray campaigns. These technologies could be used to demonstrate the likely extent of drift of spray material and could provide needed input to existing and future spray drift models.

- A proposed new modeling approach, which uses parameterizations from multiple runs with a full-physics atmospheric transport model, should be investigated as a better long-term solution to a broader range of complex terrain aerial spraying problems. This modeling approach holds the promise of working effectively on any actual 3-dimensional topography. Further, it could be combined with other modeling approaches that use digital elevation models of the actual topography of the spray blocks.

- Finally, an effort should be made to develop links with scientists doing research in complex terrain meteorology, and to follow future developments in full-physics modeling as computer power increases.

- See Dave's report in Appendix C.

B. Non-Attendees Reports/Letters

<u>Sandra Bird</u>

- See Sandra's letter in Appendix D.

<u>Fred Bouse</u>

- See Fred's letter in Appendix D.

<u>Bob Mickel</u>

- Offered to host next meeting (1992) in Sault Ste. Marie, Canada.

- See Bob's fax message in Appendix D.

Dave Miller

- See Dave's note to Karl Mierzejewski in Appendix D.

Al Womac

- See Al's letter in Appendix D.

C. Special Report

Dave Miller, through Karl Mierzejewski, reported (see Dave's report in Appendix D) that FSCBG predictions compared to field data collected in an oak forest were off 50% to 100% to the 1988 field test's observed data. Questions were raised on the collection efficiency of the field samplers, effects of forest openings on air flow and micro-meteorology, and inputs to FSCBG. Karl was not in a position to answer these questions. Therefore to pursue these questions, Mike McManus suggested that Dave Miller and Milt Teske meet to review FSCBG inputs and comparison of outputs to field data. See Milt Teske's report of visit with Dave Miller that follows. This incident demonstrates that researchers should understand the model before conducting tests to verify predictions.

TRIP REPORT
Milton E. Teske visiting Dave Miller and Dean Anderson
University of Connecticut
October 8, 1991

Background

At the recent National Spray Model Advisory Committee meeting on September 12 and 13, 1991, in Blacksburg, Virginia, Dave Miller (in absentia) presented a summary of his comparisons of FSCBG predictions with recent field data. His concerns centered on the inability of the model to compare as favorably with the field data as he would like; in particular, he repeatedly cited the fact that FSCBG predicts the ensemble-averaged dispersion, and tentatively concluded that one should be cautious about using the model to specifically plan individual field operations. The comparisons backing up these statements are contained in a draft paper entitled "Deposition of Aerially Applied BT in an Oak Forest and its Prediction with the FSCBG Model," by Dean E. Anderson, David R. Miller, Yansen Wang, William G. Yendol, Karl Mierzkjewski and Michael A. McManus. At the urging of Mike McManus, a meeting was arranged in Storrs, Connecticut, on Tuesday, October 8, 1991, to discuss this topic and related issues.

Overview

A review of FSCBG predictions compared with field data (presented in the draft paper) indicated the surprising result that nearly all predictions gave the same deposition level, plume spread and downwind drift location at the top of the canopy. This result comes from the AGDISP Near Wake model contained in FSCBG. In previous work I have always been able to get AGDISP to predict the deposition in the general location of the data (a function of the crosswind velocity), with approximately the correct standard deviation (a function of the background turbulence level). Upon closer examination, it became clear that Dean Anderson had not set the proper turbulence level or crosswind velocity for any of the model simulations contained in the draft paper, and upon which Dave Miller based some of his observations at Blacksburg. Dean Anderson was surprised that menus even existed in FSCBG to input these variables.

Consequences

All of the statements made by Dave Miller regarding model comparisons are now on hold pending the proper operation of FSCBG. He indicated a willingness to rewrite his draft paper and permit me to review it before submitting it for publication. This is good, because I am somewhat concerned by these developments. Some of the discrepancies in the original model comparisons, which were interpreted as errors in FSCBG, may have been errors in model inputs that led FSCBG to make its predictions. This exercise shows the value of attending an FSCBG training session (during which time all menus in FSCBG are discussed) or exploring the program periodically.

Recommendations

Aside from the model operation issues discussed above, Dave Miller detailed a number of suggestions for improving the model with the release of version 4.0. They are:

1. Improve the spread of the plume above the canopy. This may no longer be an issue because of incorrect inputs to the model; nonetheless, we anticipate that version 4.0 will compute the atmospheric turbulence level q^2 (used in the AGDISP Near Wake calculations) consistent with the azimuth and elevation turbulence statistics

$$q^2 = (2 \sigma_A{}^2 + \sigma_E{}^2) U_{10}{}^2$$

where all parameters are referenced to 10 meters.

2. Improve the sensitivity of the model to turbulence. Again, a proper input of the turbulence should improve above-canopy plume growth. Sensitivity to background turbulence will also be addressed in a forthcoming ASAE paper.

3. Improve the sensitivity of the model to stability. The use of the above equation should have a direct bearing on the ability of the model to respond to stability effects.

4. Improve the sensitivity of the model to crosswind. Again, a proper input of the crosswind component of the wind speed will diminish the importance of this observation. NASA in 1984 field-tested the AGDISP model at Wallops Island and found that it predicted the mean position of deposition (in crosswind) better than 96 percent of the time. In version 4.0 crosswind will be computed consistent with the entered wind speed profile.

5. Include wind shifts within the canopy. It was explained that with the ballistic trajectory assumption, wind shifts are not an easy thing to do at present. Dave was particularly concerned about bimodel ground depositions, where large spray drops land in one place, and small spray drops land somewhere else in a different direction. Since we are contemplating a shift of the dispersion solution scheme in FSCBG from integrated line source to point sources, we will keep his needs in mind.

6. Include diminished wind effects within the canopy. This is again difficult to do with the current model, but some gross effects (using as a springboard an eddy viscosity model suggested by Dave) may be able to be implemented.

7. Include dispersion within the canopy. This whole issue is tied to the present solution scheme, and is under consideration.

8. Add leaf area density to model inputs. This is a good suggestion, and dovetails with the inclusion of LiCor canopy measurements in version 4.0 as an alternate description of a canopy. It then begs the question of a straightforward (easy) way of discerning the leaf area density profile in the field.

Ongoing Relationship

It is hoped that this meeting will enable Dave Miller and me to discuss model development and data comparisons on a continuing basis. Continued review of comparisons between model predictions and data are especially important to model development. It is refreshing to note that Dave Miller will not publish the above-referenced paper without first seeking my opinion on its content.

Milton E. Teske

III. RECOMMENDATIONS

Recommendations are listed by priority with A being highest priority. Numbered recommendations under a lettered recommendation have equal priority.

A. Evaluate models that predict drift in complex/terrain and conduct drift studies in complex terrain, sampling for drift up to 5 miles downwind. This recommendation includes the additional recommendations that a "rule of thumb" manual for spraying be prepared.

B. Adapt spray models for ground sprayers, specifically airblast and orchard sprayers, for prediction of deposit on target foliage and drift.

C. Evaluate FSCBG drift predictions of downwind deposition and air concentration using existing and future field data.

D. Enhance FSCBG for total accountancy of the pesticide spray.

E. Standardize field collector sampling methods and determine sampler/collector collecting efficiencies.

F. Enhance FSCBG model for spraying in urban environments.

G. Improve deposit/witness card spread factor technology and develop method of determining spread factors in the field.

H. 1. Establish scientific acceptance of computer spray models.

   2. Develop a computer model that predicts atomization/drop spectrum.

3. Evaluate ability of FSCBG 4.0 to predict drift from ground sprayers under agricultural conditions.

I. Endorse concept of centers of excellence for pesticide application technology research.

J. Enhance FSCBG to provide "go/no-go" decisions using criteria for situations in real-time.

K. 1. Expand spray model technology transfer efforts for more acceptance by scientific community.

2. Evaluate existing computer models that predict distribution of solids and compare to AGDISP and FSCBG.

L. Enhance FSCBG to predict point of initial spray cloud touchdown. This is needed for ULV sprays applied 30 meters and higher above ground.

Other recommendations were to establish two sub-committees as listed in paragraph IV.

IV. ACTIONS

A. Sub-Committee on Meteorology

A sub-committee was appointed to develop recommendations on field meteorological measurements (types, frequency of measurements, numbers, and location) for input to computer models for validation and evaluation, and for operational use in forestry and agriculture.

Chairperson - Dave Whiteman

Members - Bob Ekblad
Jim Rafferty

It is anticipated that the sub-committee will interview other specialists thus keeping the committees small in number.

B. Sub-Committee on Models in the Regulatory Process

A meeting has been scheduled for October 23, 1991, in Salt Lake City, Utah, to discuss approaches for acceptance of computer model data for pesticide registration. The meeting will be hosted by Jim Rafferty and Jim Bowers of the U.S. Army, Dugway Proving Ground. While employees for the H.E. Cramer Co. both worked as contractors for EPA and U.S. Army in developing dispersion models.

V. SUMMARY

The second annual meeting of the **National Spray Model Advisory Committee** was held at Blacksburg, VA, September 12-13, 1991 to identify spray model needs, make recommendations, and coordinate activities. Several recommendations were developed and ranked in order of priority. Committee members noted that this year's discussions centered more on use of the models and less on model verification. Two sub-committees were established to pursue committee recommendations. The next committee meeting is tentatively scheduled to be held September 23-24, 1992, hosted by Bob Mickel at Sault Ste. Marie, Ontario, Canada across the Saint Marys River from Sault Ste. Marie, Michigan.

APPENDICES

A. Attendees and Addresses

B. Committee Membership and Addresses

C. Attendee's Reports

D. Non-Attendee's Reports/Letters

E. Recent Reports/Publications

Appendix A

Attendees and Addresses

NAME	ORGANIZATION	ADDRESS	PHONE
Jim Rafferty	U.S. Army DPG	Commander U.S Army DPG Attn: STEDP-SD-TA Dugway, UT 84022	801-831-5101
Terry Biery	U.S. AFRES	Rickenbacker, OH 43217	614-492-3106
Ellis Huddleston	NM State Univ.	Dept. 3BE Las Cruces, NM 88003	505-646-3934
Dave Valcore	SDTF/Dow Elanco	9550 Zionsville Rd. S. Campus Bldg. 304 Indianapolis, IN	317-873-7886
John Craig	LABAT-ANDERSON Inc.	2200 Clarendon Blvd. Suite 900 Arlington, VA 22201	703-525-5300 X598
Linda Abbott	USDA APHIS BBEP	6505 Belcrest Rd. Room 543 Hyattsville, MD 20782	301-436-5170
Harold Flake	USDA Forest Service	1720 Peachtree Road Atlanta, GA 30367	404-347-2989
Pat Skyler	USDA Forest Service	2121C Second Street Davis, CA 95616	916-758-4600
Milt Teske	Continuum Dynamics	P.O. Box 3073 Campus Bldg. 9A Princeton, NJ 08540	609-734-9282
Karl Mierzejewski	Penn. State Univ.	Pesticide Lab University Park, PA 16802	814-863-4432
Duan Baozhong	Penn. State Univ.	Pesticide Lab University Park, PA 16802	814-863-4432
Jack Barry	USDA Forest Service	2121C Second Street Davis, CA 95616	916-758-4600

September 12-13, 1991

ATTENDEES
NATIONAL SPRAY MODEL
ADVISORY COMMITTEE MEETING
Blacksburg, VA

NAME	ORGANIZATION	ADDRESS	PHONE
Mike McManus	USDA Forest Service	51 Mill Pond Road Hamden, CT 06514	203-773-2028
Dave Esterly	E.I. DuPont (SDTF)	P.O. Box 30 Newark, DE 19714	302-451-0018
Brian Richardson	Forest Research Inst.	Private Bag 3020 Rotorua, New Zealand	073-475-899
Dave Whiteman	Battelle NW Labs	P.O. Box 999 Richland, WA 99352	509-376-7859
Doug Sommerville	U.S. Army CRDEC	Commander U.S. Army CRDEC Attn: SMCCR-RSP-P Aberdeen PG, MD 21010	301-671-4348
Steve Knight	USDA APHIS PPQ	6505 Belcrest Road Room 816 Hyattsville, MD	301-436-8716
Scott Cameron	Texas Forest Service	P.O.Box 310 Lufkin, TX 75902	409-639-8170
Richard Reardon	USDA Forest Service	180 Canfield St. Morgantown, WV 26505	304-285-1566
David W. Rising	USDA Forest Service	Tech. & Dev. Center Ft. Missoula Bldg. No. 1 Missoula, MT 59801	406-329-3900
Robert Ekblad	USDA Forest Service	Tech, & Dev. Center Ft. Missoula Bldg. No. 1 Missoula, MT 59801	406-329-3900
Bruce Grim	U.S. Army DPG	Commander U.S Army DPG Attn: STEDP-SD-TA Dugway, UT 84022	801-831-3371

How to Extend the Data Base

The Problem: $$$
The Solution:

1. Can we correlate the available data to fill in data gaps and extend the data base to spray materials, nozzles, and mission parameters not tested?

2. Can we examine the atomization process to extract by dimensional analysis the phenomena behind the process, then use our data base to confirm our approach?

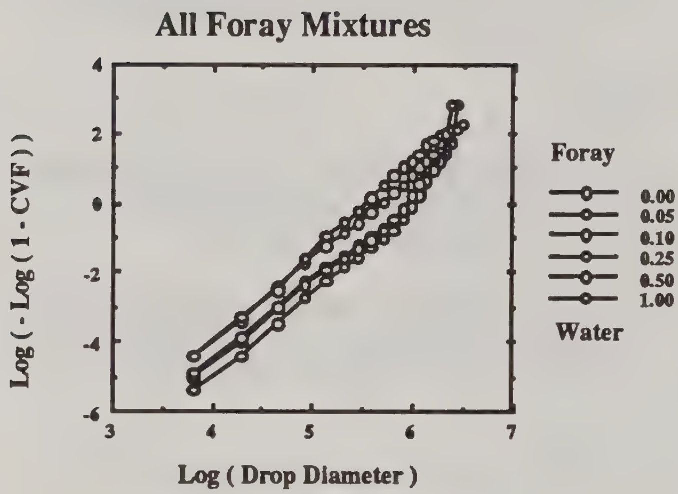
3. Or do we just continue wind tunnel testing?

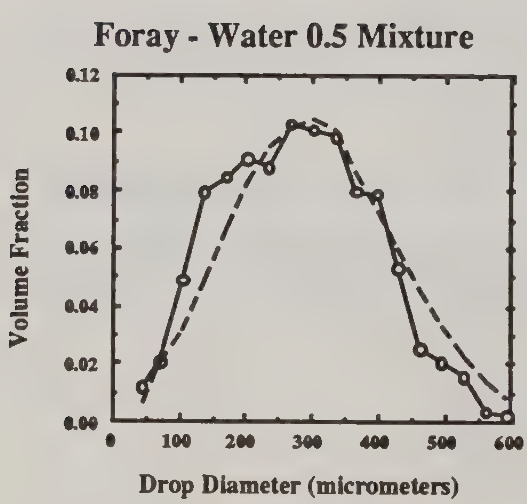
Correlation Example

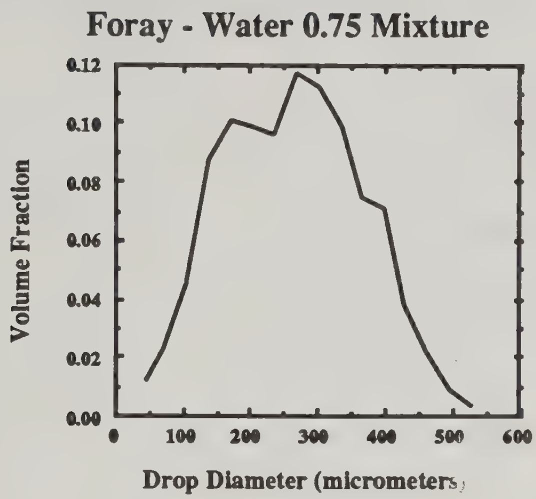
Spray Nozzle: 8004 Flat Fan at 90 degrees to a 100 mph air stream

Spray Material: Foray 48B -- Bacillus thuringiensis

Dilutions with water: 0 percent ("neat"), 5 percent, 10 percent, 25 percent, 50 percent, and all water with no Foray in mixture with it


All Foray Mixtures
Log (- Log (1 - CVF))
Log (Drop Diameter)
Foray
0.00
0.05
0.10
0.25
0.50
1.00
Water


Foray - Water 0.5 Mixture
Volume Fraction
Drop Diameter (micrometers)



User Group Report

AGDISP: 34 members FSCBG: 31 members

AGDISP 6.0 released in the spring; FSCBG 4.0 this fall

Field questions about code operation and sensitivity of input variables -- to this end we anticipate a full and complete sensitivity study of ALL inputs to the models

Published our second newsletter this summer

Continuum Dynamics, Inc. won competitive contract

FSCBG training session: November 5-8, Las Cruces NM

Anticipated FSCBG Improvements

Li-Cor canopy description
Laser printer support
Enhanced graphics (Halo)
Discrete receptors
Data export
Swath width evaluation
Library extensions
On-line help
Run time estimation

Other Future Modeling Efforts

ASCAS -- Automatic Spot Counting And Sizing
Comparisons with data: Alexander spring creek (drift);
C-130 and Davis aircraft spray trials
Drop size scaling analysis
Property estimation for evaporation
Complete sensitivity study
Statistically averaged quantification
Collapsing drop size data base

Appendix D

Non-Attendee's
Reports/Letters

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
ENVIRONMENTAL RESEARCH LABORATORY
COLLEGE STATION ROAD
ATHENS, GEORGIA 30613-7799

September 10, 1991

OFFICE OF
RESEARCH AND DEVELOPMENT

Jack Barry
USDA Forest Service
WO/Forest Pest Management
2121 C 2nd Street
Davis, CA 95616

Dear Jack:

I will not be able to attend the meeting in Blacksburg Sept. 12-13. As input to the meeting however, I wanted to write you a brief note with regards to my spray drift modeling plans/concerns. My major concern is the ability of FSCBG to predict offsite drift relative to agricultural applications in the downwind direction. Existing studies do not sufficiently address this question. The heather seed orchard study does not test FSCBG for downwind drift and the Project Wind (Rafferty, 1988) technical report suggests the model drops off more rapidly than the data for the downwind tails.

I am planning to do model testing using EPA-OPP file studies and existing published literature for agricultural applications during Fall 1991. A preliminary test I did with Version 3.0 suggested, as did the Rafferty results that the simulation deposition results drop off more rapidly at the downwind tails than the field data. A tendency to underpredict this offsite deposition is of concern relative to the type of uses and interests that the EPA has for a spray drift model.

I will continue to pursue this project with Version 4.0. I am currently working with Version 4.0 using the simplified wake and dispersion models. The complex wake/dispersion coupled mode appears to produce erratic results. Milt says he hopes to have this problem resolved in October.

The interface for Versions 4.0 is straightforward. Incorporating the aircraft and nozzle libraries is very useful and expanding this approach, as it appears you plan to do from the structure of the interface, would be useful. The plotting package is very usable. The main addition which I would like to see added to the plot routines is the capability to plot field test results on the x/y dispersion plots.

I hope your meeting is productive. If you have any questions or need any clarification of the issues I have mentioned, feel free to call me at FTS 250-3372 or 404-546-3372.

Sincerely yours,

Sandra L. Bird

Sandra L. Bird
Environmental Engineer

United States Department of Agriculture

Agricultural Research Service

Southern Plains Area
Southern Crops Research Laboratory
Pest Control And Application
Systems Technology Research Unit
231 Scoates Hall, Texas A&M University
College Station, Texas, USA 77843-2122
Phone: 409-260-9364 FAX: 409-845-3932

Septer ıer 3, 1991

John W. Barry
USDA-FS
2121 C Second Street
Davis, CA 95616

Dear Jack:

Due to a lack of funds and to a conflict with preparation for an ARS Research Planning meeting I will be unable to attend the ational Spray Model Advisory Committee meeting in Blacksburg on September 12-1.

During the past year we have had very little activity with AGDISP. The Mod 6.0 version was received and checked out in May. Dr. Buddy Kirk provided the rest of us with a brief review of changes in the program. We are pleased that several of our suggestions and the aircraft library that we helped edit have been incorporated.

Our research unit has continued to collect spray deposition and canopy penetration data in cotton under Dr. Kirk's leadership. This data may be useful in a data base for adding agronomic crop plant canopy deposition/penetration parameters in future versions of the code. Unfortunately, due to limitations and difficulties with using previously available instrumentation, data on plant canopy characterization is limited. Our canopy measurement system has been upgraded this summer and improved canopy characterizations should be possible for future studies.

I appreciate the invitation to participate in the meeting and regret that we are unable to do so. We continue to be interested in the models and in possibly providing data for validation and for improving their applicability to agricultural situations. Dr. Eric Franz of our unit plans to participate in the FSCBG training in Las Cruces.

Sincerely,

L F Bouse

L. F. Bouse
Research Leader

Appendix B

Committee Membership and Addresses

Final Summary

We have released latest versions of both models

We are continuing to compare predictions with field data to improve the models (and publish reports)

We are expanding model features in response to user needs and anticipated model requirements over the next several years

We are conducting training: one on one; Las Cruces

Our technology is being used beyond the USDA Forest Service

The Work Ahead

Many of our future improvements are a direct result of suggestions made at training sessions or by users, some of whom are here today.

Through the AGDISP and FSCBG User Groups, we strive to respond to what you would like the models to do.

The USDA Forest Service has funded these efforts in the past, and will support continued improvements to the models. But the user community will also need to get involved. The codes are maturing. Ideas are always welcome.

Model Publications: Reports Produced in the Last Year
1990-1991

A. J. Bilanin, M. E. Teske, J. W. Barry and R. B. Ekblad: "USDA Forest Service Aerial Spray Dispersion Models AGDISP and FSCBG. I: Model Formulation. II: Model Validation," Pesticides in the Next Decade: The Challenges Ahead, Proceedings of the Third National Research Conference on Pesticides, Richmond, pp. 772-791, November 1990.

M. E. Teske, T. B. Curbishley, J. W. Barry and R. B. Ekblad: "FSCBG: An Aerial Spray Dispersion Model for Predicting the Fate of Released Material Behind Aircraft," Society of Environmental Toxicology and Chemistry (SETAC) Annual Meeting, Arlington, p. 77, November 1990.

M. E. Teske, T. B. Curbishley, J. W. Barry and R. B. Ekblad: "FSCBG: The Forest Service Aerial Spray Dispersion Complete-Wake Model," Resource Technology 90, Washington D. C., pp. 666-675, November 1990.

T. B. Curbishley, M. E. Teske and J. W. Barry: "Spray Dispersion Visualization Using FSCBG 4.0," Paper No. 911051, ASAE Summer Meeting, Albuquerque, June 1991.

M. E. Teske, J. W. Barry and R. B. Ekblad: "Preliminary Sensitivity Study of Aerial Application Inputs for FSCBG 4.0," Paper No. 911052, ASAE Summer Meeting, Albuquerque, June 1991.

M. E. Teske, P. J. Skyler and J. W. Barry: "A Drop Size Distribution Data Base for Forest and Agricultural Spraying: Potential for Extended Application," ICLASS-91 Fifth International Conference on Liquid Atomization and Spray Systems, Gaithersburg, July 1991.

M. E. Teske, K. P. Bentson, R. E. Sandquist, J. W. Barry and R. B. Ekblad: "Comparison of FSCBG Model Predictions with Heather Seed Orchard Deposition Data," Journal of Applied Meteorology, Vol. 30, No. 9, pp. 1366-1375, September 1991.

M. E. Teske: "An FSCBG Primer," USDA Forest Service Forest Pest Management Report No. FPM-90-10, September 1990.

M. E. Teske, T. B. Curbishley and P. J. Skyler: "FSCBG One On One Instruction Manual," USDA Forest Service Forest Pest Management Report No. FPM-90-xx; also Continuum Dynamics, Inc. Report No. 90-07, September 1990.

SPRAY DRIFT TASK FORCE

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Nick Somma
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. Charles A. O'Connor, III
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Kenna & Cuneo
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Washington, D.C. 20005
TEL: (202) 789-7586
X: (202) 789-7756

October 15, 1991

Jack Berry
USDA Forest Pest Management

cc: Max Olleiu
USDA Forest Pest Management

D. Esterly/R. Drewes
DuPont

SPRAY DRIFT TASK FORCE (SDTF) COMMENTS TO NATIONAL ADVISORY COMMITTEE ON FSCBG MODEL

Our involvement with the USFS continues in this area to be very beneficial. The now 28 member companies of the SDTF have the following priorities and suggestions.

1. Develop possible technical review mechanism for use by the EPA to approximate phenomalogical models for regulatory purposes, and/or identify qualified individual for such a task.

2. Continue sensitivity assessment of model variables.

3. Continue evaporation rate determination methodology demonstration with the D.O.D. and S.R.I. and the SDTF.

4. Finish the material accountability work with the models for ground spray scenarios.

5. Develop model capability for air blast drift prediction and ground spray scenarios.

6. Enhance and/or correct the model's bias to predict low, especially in the 100-300m downwind range.

7. Per conversations with EPA we suggest the SDC program and/or M. Teske's Drop Size program, make a note or provision to not combine or drop the smallest drop size categories (i.e. those below 150 m) when simulating downwind deposits.

The SDTF will continue some further sensitivity studies with Continuum Dynamics to investigate critical drop sizes for downwind drift and the sensitivity of the vortex decay coefficient, and inform you of results.

We will report back to the SDTF on the probably need to pick up some funding costs for further program additions such as air blast and ground applications.

Kudus to you and those involved with the meeting. This year's meeting was excellent, I believe even better than 1990, more and higher-quality information is being transferred.

Best Regards,

David L. Valcore/jmb

David L. Valcore
SDTF
Atomization & Modeling Subcommittee
(317) 873-7886

jmb

Battelle
Pacific Northwest Laboratories
Battelle Boulevard
P.O. Box 999
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Telephone (509) 376-7859

September 16, 1991

Dr. Jack Barry
Program Manager
Forest Pest Management
USDA Forest Service
2121C, 2nd Street
Davis, CA 95616

Dear Jack:

Attached is a summary of my presentation to the Blacksburg meeting of the National Spray Model Advisory Committee, and the recommendations that I made to the committee. As you requested, I have also attached a copy of a chapter that I wrote recently for the AMS monograph series dealing with complex terrain meteorology. Please let me know if any of the material needs further explanation.

As you suggested, I have reviewed our past correspondence dealing with a complex terrain meteorology manual focused on providing "rules of thumb," etc., for the planning and conduct of aerial spraying operations in complex terrain areas. I am still quite keen on getting this project under way and would like to discuss this idea further with you if you feel that there may be support for this project. I expect to be quite busy in FY 1992 and would suggest that we think of beginning the project early in FY 1993--that is, about a year from now. I have reviewed my original estimates of the cost of such a project and feel that it could still be done here for a cost of about $95K. I will attach to this letter a copy of the proposed outline for such a document. Note that this cost estimate assumes that you or Bob Ekblad would write Chapter 2, or that Chapter 2 would be eliminated from the document. Please note that the USDA Forest Service has an open Interagency Agreement with our laboratory, and this simple mechanism has worked well as a contracting mechanism in our past work. I recognize that finding the necessary funding may be a real challenge given the present budgetary climate. Nevertheless, such a manual would be a very important product that would prove useful to the Forest Service and to a multitude of other groups dealing with complex terrain forest and agricultural spraying issues.

Thanks for the invitation to become a member of the Committee and the opportunity to participate in the Blacksburg meeting. I found the committee meeting to be stimulating, and enjoyed having the opportunity to get to know the other participants.

Best Wishes,

Dave White

C. David Whiteman
Staff Scientist
Atmospheric Physics
ATMOSPHERIC SCIENCES DEPARTMENT

CDW:rak

Enclosures

Summary of Blacksburg Presentation of 9-12-91

C. D. Whiteman

- Meteorology in complex terrain areas differs from meteorology over flat terrain areas. Over complex terrain, thermally driven circulations are generated when boundary layers form over inclined surfaces. The meteorology during the morning transition period, when spraying is usually conducted, involves multiple interacting layers in the wind and temperature structure. Additional complications come from specific topographic effects and the degree of coupling between the winds within and above the complex terrain area. Forest pesticide spraying in mountainous areas must be cognizant of these meteorological differences.

- Existing FSCBG and AGDISP models were not designed to predict dispersion over complex terrain areas, and will need modification to handle complex terrain situations properly.

- Several initial modeling approaches are underway to improve complex terrain modeling performance. First, a solar shading algorithm has been combined with USGS digital elevation models to predict isochrones of sunrise time in specific valleys at different times of the year. Such isochrones should prove useful in future planning of aerial spraying campaigns. Second, modifications are presently being made to a phenomenological model originally developed for the EPA, called VALMET, to optimize it for predicting drift in confined valley topography. CDI has demonstrated that results from such a model could be output using the AGDISP plotting routines. Also, the modified VALMET model will take advantage of AGDISP calculations for determining the non-deposited fraction of the sprayed material.

Suggestions for the Committee: 9-12-91

C. D. Whiteman

- A manual describing complex terrain meteorological phenomena and their effect on aerial spraying operations should be commissioned. This manual should provide useful rules of thumb, simple algorithms for making relevant meteorological calculations, nomograms, tables, etc. that would be useful for the planning and conduct of aerial spraying operations.

- The Forest Service should implement, in-house, a technique recently demonstrated by Battelle to use digital elevation models and solar shading algorithms to aid in the planning of future spraying campaigns in complex terrain areas.

- The existing EPA model, VALMET, should be modified and optimized for aerial spraying in confined valley situations. Initial work is presently under way.

- New Doppler mini-sodar and aircraft navigation (GPS) technologies should be investigated for routine incorporation into spray campaigns. These technologies could be used to demonstrate the likely extent of drift of spray material and could provide needed input to existing and future spray drift models.

- A proposed new modeling approach, which uses parameterizations from multiple runs with a full-physics atmospheric transport model, should be investigated as a better long-term solution to a broader range of complex terrain aerial spraying problems. This modeling approach holds the promise of working effectively on any actual 3-dimensional topography. Further, it could be combined with other modeling approaches that use digital elevation models of the actual topography of the spray blocks.

- Finally, an effort should be made to develop links with scientists doing research in complex terrain meteorology, and to follow future developments in full-physics modeling as computer power increases.

Proposed Outline

Meteorological Aspects of Forest Pesticide Spraying in the Western U.S.

1. Introduction
2. Spraying Parameters
    - 2.1 A typical Spraying Scenario
    - 2.1 Timing
    - 2.3 Spray Plane and Nozzle Configuration
    - 2.4 Deposition and Drift
    - 2.5 Modeling
3. Fundamentals of Valley Meteorology
    - 3.1 Valley Wind Systems
    - 3.2 Temperature Inversions
    - 3.3 The Morning Transition Period
    - 3.4 Effects of Topography
    - 3.5 Effects of Surface Energy Budget
    - 3.6 Effects of the Forest Canopy
    - 3.7 Effects of Upper Air Flows
4. Quantifying and Estimating the Timing of Events Affecting Forest Pesticide Spraying
    - 4.1 Temperature Inversion Breakup
        - 4.1.1 Inversion Breakup Algorithm
    - 4.2 Sunrise and Solar Shading
        - 4.2.1 Digital Terrain Models
        - 4.2.2 Insolation Nomograms
        - 4.2.3 Cloud Algorithms
        - 4.2.4 Soil Moisture Algorithms
    - 4.3 Valley and Slope Wind Systems
        - 4.3.1 Their Interaction as a Function of Time (Climatology)
        - 4.3.2 Effects of Valley Size and Climatic Regime
    - 4.4 Boundary Layer Growth Over the Slopes
        - 4.4.1 Brehm Algorithm
        - 4.4.2 Schumann Model
5. Example Use of Algorithms in Planning a Spraying Campaign
6. Summary and Conclusions

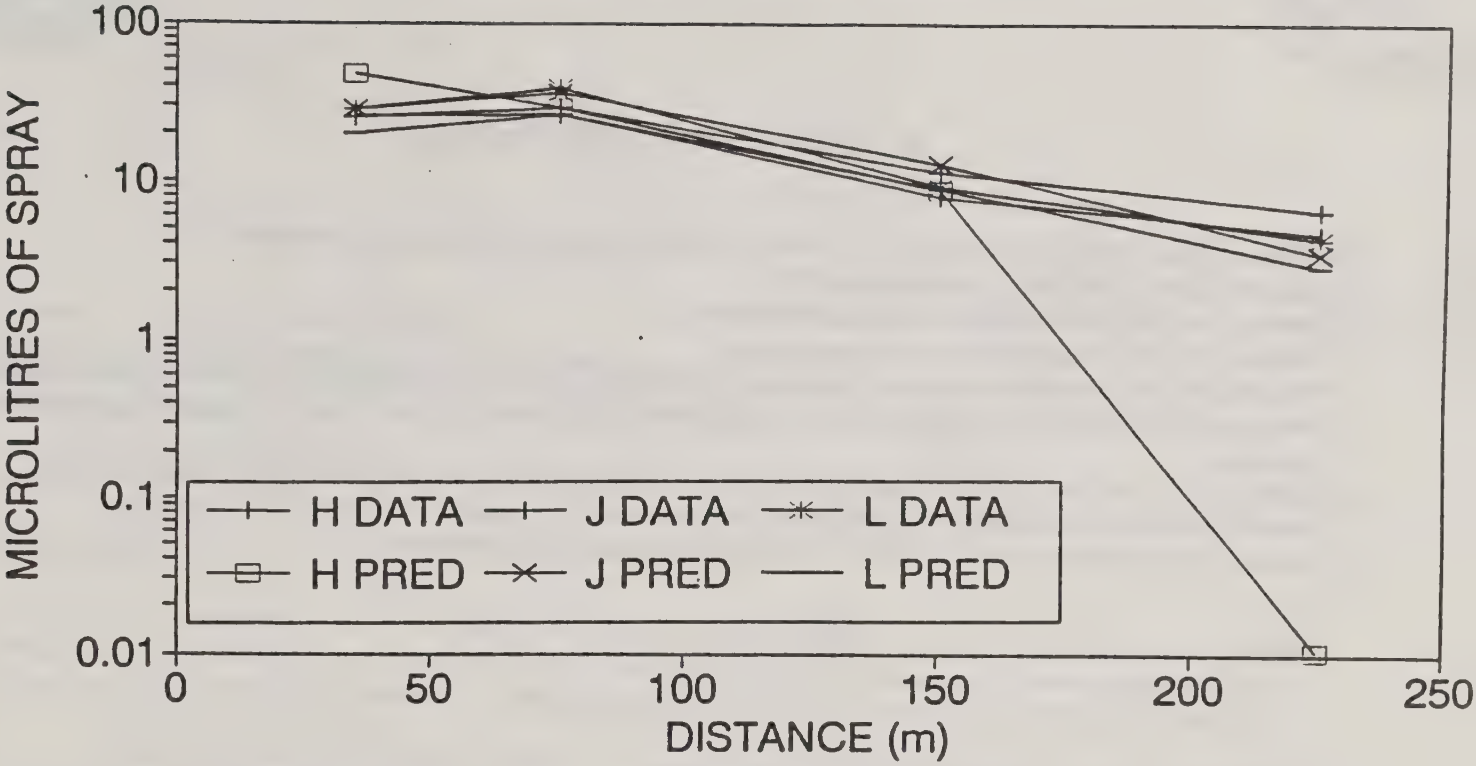


Figure 6: Mean rotorod data versus predictions for D8-45 nozzles.

CONCLUSIONS

FSCBG has proven to be excellent for predicting:

- Relative treatment effects.
- Deposition close to the aircraft (up to 50 - 100 m downwind).
- Position of the peak deposit.
- Airborne levels of spray.

Spray deposition at distances greater than 50 - 100 m downwind is underestimated by FSCBG, and predictions show erratic behaviour. Until these problems are solved, it is probably not appropriate to use the model for calculating buffer zones.

REFERENCES

Yates, W.E., Akesson, N.B. and Cowden, R.E. 1984. Measurement of drop size frequency from nozzles used for aerial application of pesticides in forests. USDA Forest Service Report, Equipment Development Centre, Missoula, Montana. 3400-Forest Pest Management, 8434 2804.

FUTURE FSCBG DEVELOPMENTS

The following list outlines future needs, in order of priority, from a New Zealand perspective:

1. Improve abilty of FSCBG to predict spray drift.
2. Continue with sensitivity analysis and validation trials.
3. Develop FSCBG/AGDISP for solids applications.
4. Further develop the canopy model and include an option for discrete areas of canopy within the receptor grid.
5. Develop FSCBG/AGDISP for ground-based applications (e.g. tractor mounted boom or horticultural air-blast sprayers).
6. Modify FSCBG so that a plot of cumulative deposition verus distance can be generated. In other words, this would allow one to state that x% of the spray has deposited by y metres downind of the spray block.
7. Consider incorporating results of FSCBG sensitivity analyses into a database.

DEPARTMENT OF THE ARMY
U.S. ARMY CHEMICAL RESEARCH, DEVELOPMENT AND ENGINEERING CENTER
ABERDEEN PROVING GROUND, MARYLAND 21010-5423

REPLY TO ATTENTION OF SMCCR-RSP-P

September 12, 1991

John W. Barry, Chairperson
National Spray Model Advisory Committee
c/o United States Department of Agriculture
Forest Service
2121 C Second Street
Davis, CA 95616

Dear Jack:

In reference to our earlier phone conversation, I have prepared a brief summary (enclosed) of CRDEC's (U.S. Army Chemical Research, Development, and Engineering Center) comments concerning the AGDISP (v. 6.0) computer model.

Most of these comments are the result of work performed by Mr. Stephan Ullah, an undergraduate at Coppin State College, Baltimore, MD. Mr. Ullah has been assisting me in the evaluation of the user friendliness (in reference to the particular needs of CRDEC) of the software and comparing AGDISP to models developed by CRDEC.

If there any questions concerning these comments, please contact me at 301-671-4348/3058.

Sincerely,

Douglas R. Sommerville
Chemical Engineer

Enclosures

AGDISP (v. 6.0)
US ARMY CRDEC COMMENTS

1. User Friendliness:

We have found the PC version of AGDISP to be very user friendly and easy to learn. The control center and editor are excellent. Documentation is easy to follow and understand.

2. Flexibility in Data Sub-directories:

The current version of AGDISP does not allow the use of data files located outside the directory where the executable files are stored. Separation of the data files and output files from the executable files is desirable for reasons of housekeeping and trouble-shooting. CRDEC recommends that for a future PC version this situation be corrected.

3. Assumption of Isothermal Evaporation:

During comparison of AGDISP with CRDEC's NUSSE model in reference to the evaporation of free-falling droplets, a discrepancy was noted between the predictions of the two models. Droplets in the AGDISP model had a higher evaporation rate than NUSSE droplets. A phone conversation with Milton Teske, Continuum Dynamics, resolved the problem--AGDISP essentially assumes that droplet free-fall evaporation is an isothermal process.

The assumption of isothermal evaporation is a good one for low release heights, and we had been comparing the two models at an altitude (300 meters) where the assumption was no longer reasonable. To avoid future confusion, it is suggested that the isothermal assumption be explicitly stated in future AGDISP documentation.

4. Upcoming Spray Characterization Work:

Mr. Alan Seitzinger, Physics Division, CRDEC, will be conducting calibration trials of a recently constructed ground spraying system. The system was designed to spray (for testing and evaluation purposes) a ground area or military vehicles with a reproducible liquid contamination density and droplet size distribution. I have discussed with Mr. Seitzinger the possibility of furnishing the spray nozzle characterization data obtained to the USDA Forest Service for inclusion into their spray nozzle data base, and Mr. Seitzinger expressed interest in the idea.

In addition, the Physics Division ground sprayer could be used to provide validation data for the ground sprayer option of the AGDISP model. Mr. Seitzinger should be contacted (301-671-4470) for more information or arrangements.

5. <u>Incorporation of Non-aqueous Liquids in Model</u>:

For future versions of AGDISP, CRDEC recommends that a card be incorporated into the model to account for fluid properties that may be substantially different from that of water (ie. density, volatility, heat of vaporization, etc.).

6. <u>Research into the Use of Different Witness Card Material</u>:

Dr. Joseph Matta, Ms. Angela Farenwald, and I, have been looking into the use of other materials, besides the traditional paper products, currently being used in witness cards. Preliminary work with teflon sheets have been promising. The droplets dry nicely and give a sharp contrast against the card background. For subsquent spectroanalysis, solvent extraction of the tracer dye is simple and straightforward. If there is any interest, CRDEC can use USDA Forest Service liquids with the teflon sheets to see if they would be better than the Kromekote cards currently used.

For future versions of ADDISP, CADPC [illegible] that a card to incorporate into the model to account for fluid properties that may be substantially different from that of water (ie. density, volatility, rate of vaporization, etc.).

We have found the PC version of [illegible] [illegible]

Dr. Joseph Motta, Ms. Angela Varenwald, and I, have been looking into the use of other materials, besides the traditional paper, [illegible] being used in witness cards. Preliminary work with teflon sheet have been [illegible]. The droplets dry quickly and give a good contrast against the card backing. For example, when sampling a solvent [illegible] of the stain [illegible] dye is [illegible] and [illegible]. [illegible] a [illegible] [illegible] better than the Kromekote [illegible] [illegible]

8. [illegible] [illegible] [illegible]

[illegible] [illegible] [illegible] [illegible] [illegible] [illegible] (Micropore) [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] in Milton [illegible] [illegible] [illegible] [illegible]

[illegible] [illegible] [illegible] a good one for low release [illegible] altitude (200 meters) [illegible] [illegible] future [illegible] [illegible] [illegible] future

[illegible]

[illegible] [illegible] will in conducting [illegible] [illegible] [illegible] [illegible] [illegible] density and [illegible] designed to [illegible] [illegible]

USDA Forest Service
Aerial Spray Models
AGDISP and FSCBG

1991 Model Status Report

Milton E. Teske
Continuum Dynamics, Inc.

National Spray Model Advisory Committee
Blacksburg, Virginia
September 12-13, 1991

Technical Memorandum No. 91-11

Contract No. 53-0343-1-00153
John W. Barry
USDA Forest Service

Continuum Dynamics, Inc.
P.O. Box 3073
Princeton, New Jersey 08543

Program Overview

Model Development

Identification of Improvements

Some Future Modeling Efforts

User Group Activities

Summary

Over the last 20 years the USDA Forest Service and the U. S. Army have been developing computer models to predict the deposition and dispersion of aerially released spray. Their approach has been:

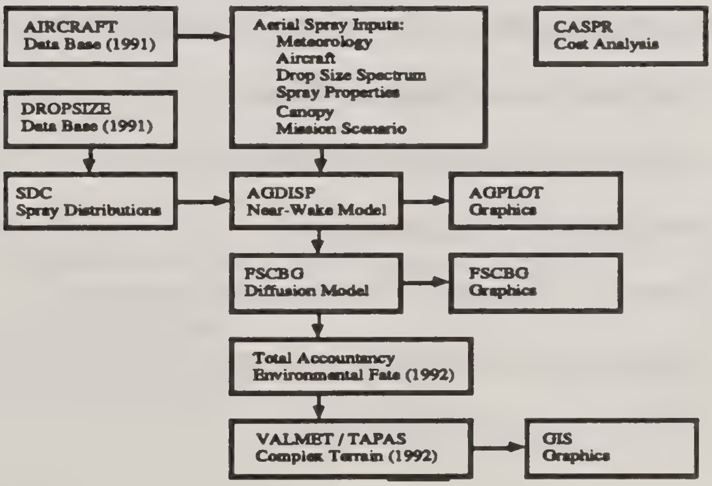
Develop predictive tools that model material fate in the atmosphere
Fashion computer models that run quickly and accurately on personal computers
Validate these models against field data
Train in the operation of these models
Support the improvement and distribution of these models to the user community

What These Models Do

AGDISP predicts the influence of near-wake aircraft features on the behavior of released spray. It gives a single swath pattern prediction by combining the effects of the spray from each nozzle.

FSCBG predicts the complete deposition and dispersion of the released spray and graphically presents quantitative results that help understand any driftable influence into buffer zones and environmentally sensitive areas.

The Whole Enchilada



The Players

USDA Forest Service

U. S. Army

U. S. Environmental Protection Agency

Spray Drift Task Force -- a consortium of 25 companies

Anticipated Model Uses

What is envisioned as uses of the aerial application models:

1. Understanding aerial application
2. Registration of pesticides (labeling)
3. Protecting our natural resources
4. Protecting endangered species (sensitive areas)
5. Monitoring airborne drift (total accountancy)
6. Validation of models (legal stuff)

The Driving Forces

Field Observation

Laboratory Experiments / Wind Tunnel Tests

Approximation

Simplification

Personal Computers

1. Engineering
2. Economics
3. Environmental Issues

The Problems

Further Validation -- especially with ground sprayers

Input Sensitivity -- identify critical inputs

Statistically Averaged Results -- model vs. field data

Total Accountancy -- off-target and downwind (time dependence and diffusion through the canopy)

Evaporation Effects

Drop Size Distributions

AGDISP Program Development

AGDISP 6.0

Editor and graphics enhanced
Up to 16 drop sizes in one run, including "to" and "fro"
Graphics: flux through a vertical plane; VMD; NMD;
COV as a function of lane separation; overlap
deposition pattern
SwathKit version
ValMet graphics
Updated user/technical manual

FSCBG Program Development

FSCBG 4.0

New user interface
Calculation modules rewritten and all equations checked
On-line libraries of dropsize distributions and aircraft
Canopy model replaced
Errors corrected in evaporation module
Atmospheric effects always computed
Simple extension of dosage/concentration within canopy
One on one instruction manual
User manual
Technical manual

Other Program Development

DROPSIZE
- 242 drop size distributions available

CASPR
- Field data comparisons: Salt Lake City

Preliminary sensitivity study (ASAE summer meeting)
DC-3 sensitivity study
SDTF

Correlating drop size data (ICLASS meeting)

Sensitivity Study

The difficulty with a sensitivity study is to present the results so that they can be compared "easily" and "effortlessly" by the reader.

Define two variables:

- Figure of Merit
- Mean Horizontal Position

Figure of Merit

Figure of Merit: A correlation that reflects the percentage change in the shape of the nonvolatile deposition pattern:

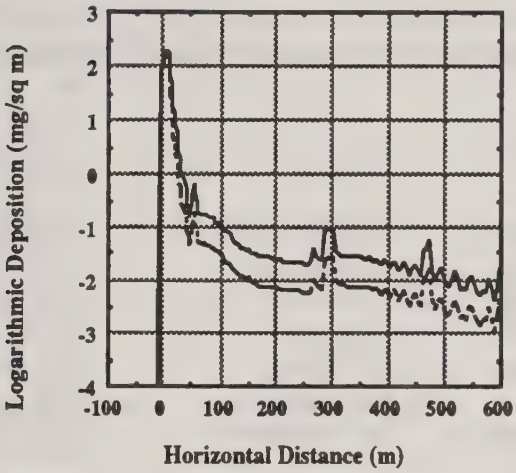
$$\mathrm{FOM} = \frac{\int c_b c_s \, dy}{\int c_b^2 \, dy}$$

Mean Horizontal Position

Mean Horizontal Position: Examine the nonvolatile ground deposition pattern to compute the volume-averaged MHP, measured downwind of the aircraft:

$$\bar{y} = \frac{\int y c_s \, dy}{\int c_s \, dy}$$

Deposition



Base Case Conditions

Aircraft Type	Bell 47G3B2
Aircraft Weight	10,800 Newtons (2,420 lbf)
Rotor Diameter	11.4 m (37.4 feet)
Aircraft Speed	17.9 m/sec (40 mph)
Release Height	15.2 m (50 feet)
Wind Speed	1.34 mph (3 mph) crosswind at 15.2 m (50 feet)
Nozzle Type	D4-45 Hollow Cone Nozzles at 90 deg to airstream
Volatile Fraction	0.942
Temperature	60 deg F
Relative Humidity	65 percent

Sensitivity Summary

Sensitivity of parameters to realize a TEN PERCENT change in Figure of Merit and/or Mean Horizontal Position:

VARIABLE	BASE VALUE	VARIATION
Aircraft Weight	2,420.0 lbf	1,000.0 lbf
Aircraft Speed	40.0 mph	10.5 mph
Release Height	50.0 feet	2.5 feet
Wind Speed	3.0 mph	0.3 mph
Wind Direction	90.0 deg	25.0 deg
Temperature	60.0 deg F	33.0 deg F
Relative Humidity	65.0 percent	22.0 percent

USDA Forest Service Data Base

Over the years wind tunnel measurements have been made to determine the drop size distribution of spray material from nozzles:

Spray Material: Dipel, Esteron, Foray, Garlon, Glycerine, Roundup, Thuricide, Water, Water with additives -- in many mixtures with Water

Nozzles: Flat Fan, Hollow Cone, Jet, Raindrop, Rotary

242 separate entries in a data base and retrieval program DROPSIZE freely available to anyone who would like a copy (personal computer)

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Appendix C

Attendee's Reports

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Milt Teske

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Dave Whiteman

REPORT TO THE NATIONAL SPRAY MODEL ADVISORY COMMITTEE

RESEARCH AND FUTURE NEEDS RELATED TO THE FSCBG AND AGDISP COMPUTER MODELS: A NEW ZEALAND PERSPECTIVE

Brian Richardson

INTRODUCTION

There has been considerable interest in New Zealand, particularly from the forest industry, in aerial spray models. It is hoped that spray modelling will help to define optimum spraying prescriptions, to maximise on-target deposition and minimise drift. Spray models are also seen as a powerful research and training tools, and provide evidence of good planning. Virtually all aerial spray application in New Zealand's exotic forests is to control either weeds or *Dothistroma pini*, a fungal disease. There are no significant insect problems.

Since the last meeting of the National Spray Model Advisory Committee (September 1990, Atlanta, Georgia) there has been an active programme to evaluate FSCBG for use in New Zealand. The two major activities of the last 12 months have been:
1. A limited sensitivity analysis to identify factors, and levels of those factors, which have a large effect on spray drift.
2. A field trial to provide data for validating FSCBG in terms of deposition and drift.

A brief summary of each of these activities is given below, followed by future development needs from the New Zealand perspective.

1. FSCBG SENSITIVITY ANALYSIS: RECOMMENDATIONS FOR MINIMISING HERBICIDE SPRAY DRIFT

BACKGROUND

The objective of this study was to identify factors and levels of those factors which have a large effect on spray drift, and to provide recommendations to minimise spray drift.

METHODS

Factors, and factor levels for inclusion in the analysis were based on the results of a questionnaire sent to all FSCBG cooperators in New Zealand.

A standard, or reference, scenario was defined. The predicted levels of deposition for the standard, at any distance downwind from the centre of the flightline, were used as reference points from which to compare the results of changing one or more variables. Comparisons with the standard were made by calculating the relative deposit for each test simulation:

Relative deposit = Test scenario deposit / Standard scenario deposit

DESCRIPTION OF STANDARD SCENARIO
(a) Models selected
- Complex Wake

- Evaporation
- Deposition
- Dosage

(b) Aircraft and operational factors

Aircraft type:	Bell Jet Ranger
Average weight:	1205 kg
Rotor diameter:	10.2 m
Blade RPM:	350
Boom length relative to rotor:	100%
Boom height (flying height):	3 m
Flying speed:	83 km/hr (45 kts)
Nozzle:	D8-45, 90° (straight down).

(c) Meteorological factors

Values for meteorological variables used in the standard scenario were as follows:

Atmospheric pressure:	1015 mb
Radiation index:	2
Atmospheric stability:	stable (inversion)

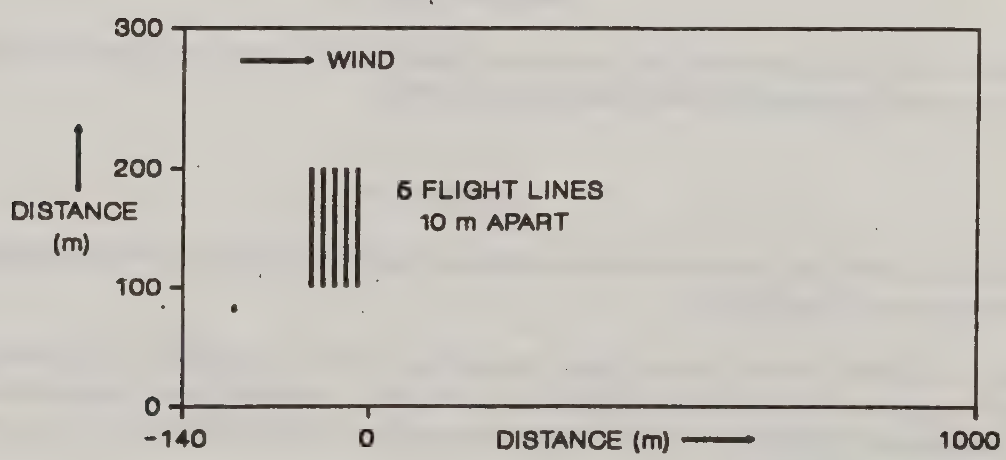
Wind speed and direction, temperature, and relative humidity data were input as profiles, but characteristic values of these variables are given below for one height only:

Windspeed at 1.25 m:	3.2 km/hr
Temperature at 2.5 m:	8.5°C
Relative humidity at 2.5 m:	93%.

The wind direction was at 90° to the flight direction.

(d) Spray site description

A diagram showing the spray site layout and flightline location is shown below:



DROPLET SIZE DATA

Droplet size information was taken from results of wind tunnel tests using a laser Particle Measuring System and water as the spray liquid (Yates et al., 1984). The only exception was for the foaming nozzle, where data was taken from a field trial conducted by FRI. Unless otherwise stated, nozzles were orientated straight down, at 90° to the wind flow.

VARIABLES TESTED

The effect of selected variables on deposition was examined by systematically changing their values. The variables tested are summarised below.

(a) Aircraft and operational factors

The following aircraft and operational characteristics were tested:
- Relative boom length (boom length relative to rotor diameter/wingspan).
- Interactions among aircraft type, relative boom length, and nozzle type.
- Boom height
- Flying speed
- Interactions among boom height, flying speed and relative boom length.

(b) Meteorological factors

Meteorological variables included in the analysis were:
- Atmospheric stability
- Temperature
- Relative humidity
- Mixing depth
- Interactions between temperature and relative humidity.

(c) Specific aircraft/nozzle combinations

A number of specific aircraft/nozzle combinations were evaluated:

Jet Ranger	- D8-45, 90° (straight down)
	- D8-45, 0° (straight back)
	- D8-46, 90°
	- D8-46, 0°
	- Microfoil boom
	- Foaming nozzles
	- Raindrop (RD7), 0°
Fletcher	- D8-45, 90°
	- D8-45, 0°
	- D8-46, 90°
	- D8-46, 0°
	- D8, 0°
	- D8, 90°
	- Raindrop (RD7), 90°
	- Raindrop (RD7), 0°
	- Raindrop (RD10), 0°

RESULTS

As an illustration of the kind of result obtained, the effect on spray drift of flying height and speed, and of windspeed is summarised below.

Flying height and speed

The effect of flying height (height of boom above the ground) and speed were determined for a Jet Ranger fitted with D8-45 nozzles. Simulations were performed for six heights (3 - 18 m) at each of four flying speeds (27.5 -

111 km/hr). Data from all of these simulations have been summarised on a graph showing relative deposit 1000 m downwind of the flight lines (Figure 1). At a given speed, as boom height increases there is only a slight increase in relative deposit until a threshold is reached. Above this threshold, further increases in flying height cause large increases in drift (relative deposit). The value of the threshold ranged from approximately 8 m at the faster flying speeds to 10 - 11 m at the slower speeds. Below the threshold, flying speed has only a minor effect on relative deposit, although there may be slight benefits from flying faster. Above the threshold, relative deposit at 1000 m downwind is greatest at high speeds and is minimised at the slowest flying speed (27.5 km/hr).

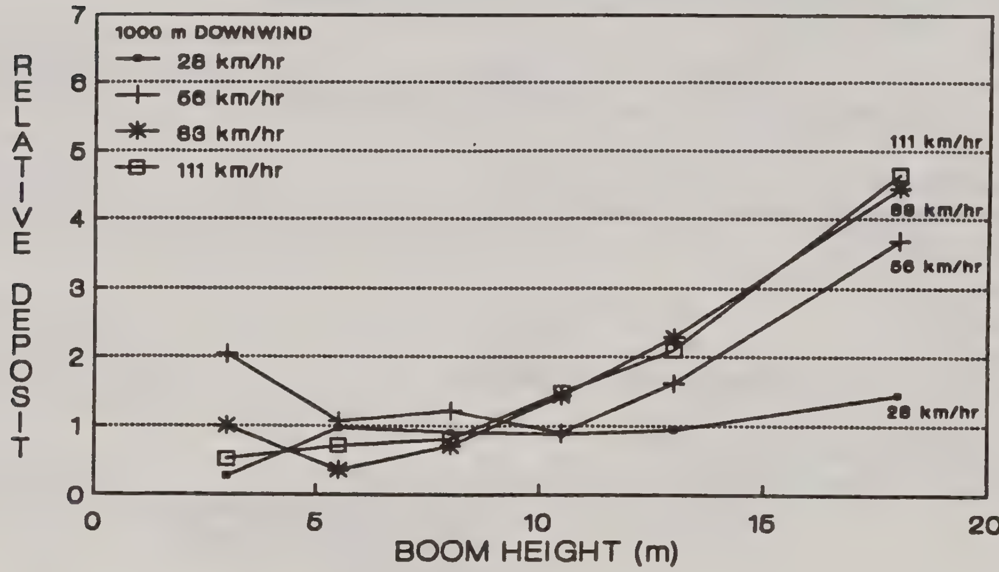


Figure 1: The effect of Jet Ranger boom height on relative deposit at 1000 m downwind, for a range of flying speeds.

Based on these results, it is recommended that boom height is kept below 10 m if possible. Below this height, flying speed is not critical in terms of drift although there may be some slight benefit from flying fast, and this will also increase productivity. Above a flying height of 10 m, drift can be minimised with a helicopter by flying slower.

(b) Windspeed

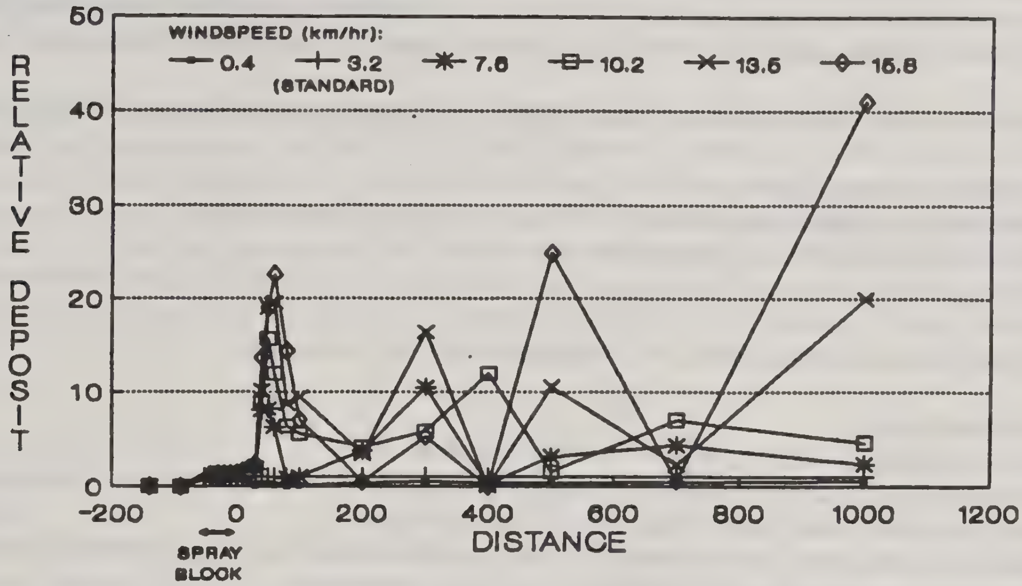
As windspeed was increased, relative deposit downwind of the spray block also tended to increase (Figure 2a) to a maximum relative deposit at 1000 m downwind of over 40 times the standard scenario. The erratic nature of the drift predictions at high windspeeds is possibly due to the separation of droplet size classes. This erratic prediction presents a major difficulty in using FSCBG to quantify downwind levels of deposition. Actual measurements of spray drift usually show a smooth reduction in deposition with distance downwind.

With reference to the summarised data (Figure 2b), there appeared to be a threshold between 10 km/hr and 15 km/hr, above which drift increased rapidly with windspeed. Below the threshold there were only slight benefits, in terms of decreased drift, from lower windspeeds.

Based on these results, it is recommended that when a hazard is present and drift reduction is the prime

concern, spraying should cease when windspeeds exceed 10 km/hr. However, windspeeds less than approximately 3 km/hr should also be treated with caution because as windspeed decreases, wind direction

(a)



(b)

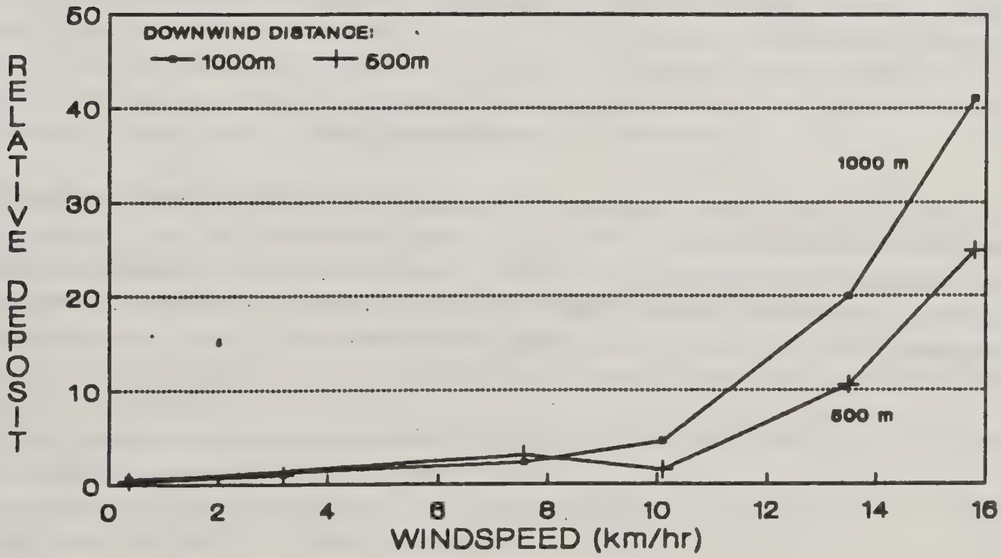


Figure 2: The effect of windspeed at 1.25 m on relative deposit for (a) various distances downwind and (b) at 500 and 1000 m downwind.

becomes less predictable. If there is a drift hazard present, spraying should be undertaken with a positive, steady wind blowing away from the sensitive area.

CONCLUSIONS and RECOMMENDATIONS

This study has illustrated the enormous potential for spray modelling. To conduct experimental trials to test all of the scenarios described above would be virtually an impossible task. However, using these techniques a series of broad recommendations has been derived which attempt to balance the needs of minimising drift within acceptable levels without excessive restriction of operational and meteorological conditions.

A summary of recommendations, taken from FSCBG predictions, to minimise spray drift is given below.

Aircraft and operational factors

1. Boom length should be less than 80% of the rotor diameter or wingspan.
2. Flying height should be no greater than 10 m.
   If flying height is less than 10 m, there may be some advantage from flying at speeds greater than 83 km/hr.
   If flying height is greater than 10 m, flying speed should be reduced.

Meteorological factors

1. Avoid spraying in a strong, shallow layered inversion.
   As atmospheric stability increases (tending to an inversion), the drift potential also increases.
2. Spraying should cease when windspeeds exceed 10 km/hr.
   Windspeeds less than 3 km/hr should be treated with caution because of variability in the wind direction.
   Spray with a positive wind blowing away from the sensitive area.
3. Cease spraying when relative humidity falls below 80%.
4. Cease spraying when temperatures rise above 20°C, although this factor is not as important as relative humidity.

Aircraft/nozzle combinations

1. Spray with nozzles orientated straight back.
2. Spray using anti-drift nozzles such as the microfoil/thru-valve boom, foaming nozzles, D8, RD7. When using these nozzles, flightlines should be premarked or flagged if possible, because of the sharp cut-off produced by the swath.

REFERENCES

Coutts, H.H. and Yates, W.E. 1968. Analysis of spray droplet distribution from agricultural aircraft. Transactions of the ASAE, 11, 25-27.

Yates, W.E., Akesson, N.B. and Cowden, R.E. 1984. Measurement of drop size frequency from nozzles used for aerial application of pesticides in forests. USDA Forest Service Report, Equipment Development Centre, Missoula, Montana. 3400-Forest Pest Management, 8434 2804.

2. FSCBG VALIDATION TRIAL

BACKGROUND

In June 1991, a trial was conducted at Tauranga airport to achieve two major objectives:
1. To generate data for the validation of FSCBG
2. To compare spray drift from three nozzle types.

For the FSCBG validation, the prime concern was to compare model predictions with measurements of downwind drift (both ground deposition and the airborne fraction of spray). The nozzle types of interest were foaming nozzles (Delafoam, Delevan Co.), which are commonly used for herbicide applications in New Zealand, D8-45 nozzles and D8 nozzles pointing straight back. D8-45 nozzles were used to represent an industry "standard", whereas D8 nozzles pointing straight back are known to produce relatively few fine droplets.

A full analysis of the Tauranga trial has still to be completed. However, a summary of some important results is given below.

METHODS

TREATMENTS
Three types of nozzle were fitted to the boom of a Bell 206 Jet Ranger:
- D8-45, pointing straight down.
- Foaming nozzles, pointing straight down.
- D8, pointing straight back.

The foaming nozzle and D8 treatments were each replicated three times. Each of these treatments was "paired" with a D8-45 treatment (giving a total of six D8-45 replicates) which was used as a standard throughout the duration of the trial.

SAMPLING SCHEME
The trial layout is shown in Figure 1. A single flightline of 300 m was marked at 90° to the wind direction. For each treatment, the aircraft made three consecutive passes, at one minute intervals, along the flightline. Each pass was made in the same direction. A single sampling line was positioned at 90° to the centre of the flightline. The sampling line extended 50 m upwind of the flightline and 300 m downwind.

Throughout the trial, the following measurements were taken:
- Flying height (nominal 10 m) and horizontal distance offset from the pre-marked flightline were measured using photogrammetric methods.
- Flying speed (nominal 83 km/hr) was measured using a doppler radar system.
- Spray output was measured using a calibrated flowmeter.
- Meteorological parameters (wind direction, windspeed profiles, and temperature (wet and dry bulb) profiles were recorded up to 10 m above the ground.
- Spray deposition on the ground was measured using steel plates (115 cm^2) placed along the sampling line from 50 m upwind to 300 m downwind of the centreline (Figure 1).
- The quantity of airborne spray was measured using rotorod samplers placed at 35, 70, 150, and 225 m downwind of the centreline, and 1.5 m above the ground.

SPRAY MIXTURE
The spray mixture consisted of water, pyranin (0.2 g/litre), a fluorimetric tracer, tartrazine (10 g/litre), and Delafoam (0.4% v/v).

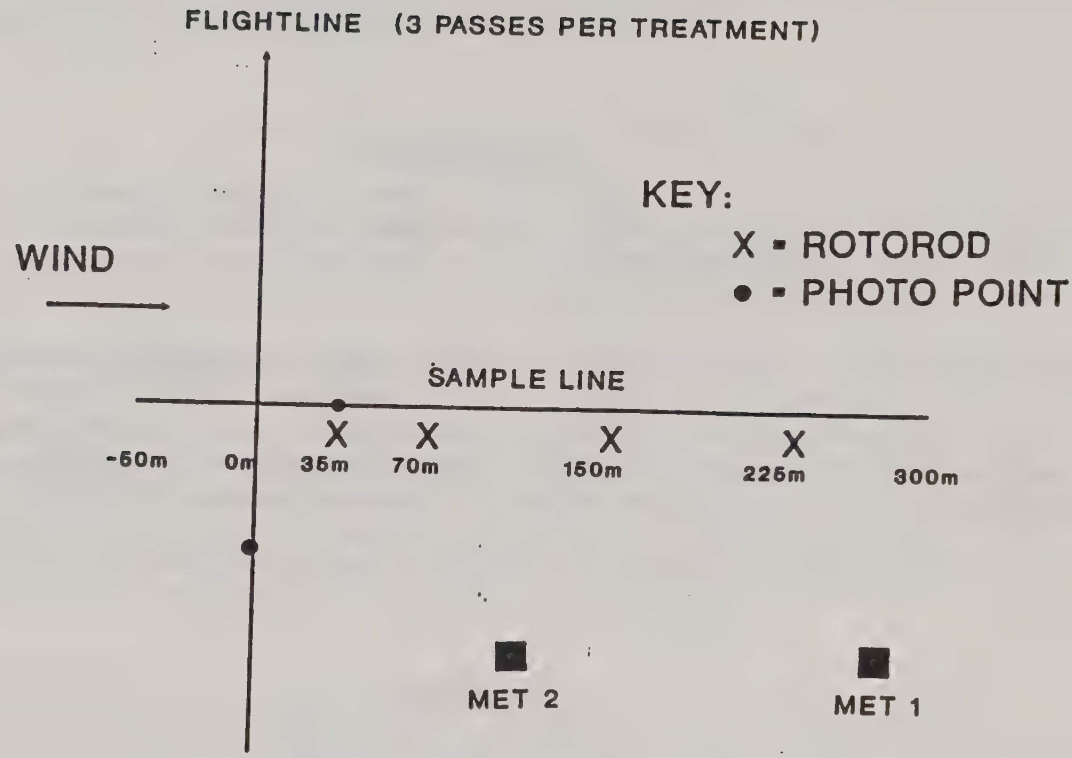


Figure 1: Sampling scheme for the Tauranga Airport trial

DROPLET SIZING
Droplet spectra for each nozzle type and orientation, using the same airspeed and spray mixture as in the trial, will be measured using a Malvern 2600 Particle Sizer (located at Werribee, Australia). Because these measurements have not yet been completed, all FSCBG simulations carried out to date have used droplet spectra data based on measurements with water (Yates et al., 1984).

RESULTS

DEPOSITION: ACTUAL DATA
Data from both the steel plates and the rotorods clearly showed that drift is minimsed by D8 nozzles pointing straight back. Highest drift levels were measured with the D8-45 nozzles.

DATA VERSUS MODEL PREDICITIONS
Preliminary comparisons of model predictions with data have been undertaken for the D8-45 and D8 nozzles. Droplet sizes for model input were taken from Yates et al. (1984), using water only. Predictions will eventually be recalculated with droplet size data using the actual spray mix.

The comparison of model predictions with data produced several conclusions:

1. The model predictions and the field data rank the nozzles and each replicate in the same order with respect to maximum deposit and drift to 300 m downwind. In other words, FSCBG provides an excellent relative comparison of treatment effects.
2. A comparison of actual D8 deposit data with predictions is shown in Figure 2. There is excellent agreement between data and predictions to about 100 m downwind. Beyond this distance, however, FSCBG substantially underestimates deposition. Note that at approximately 200 m and 700 m downwind, extremely low deposits are predicted. In the past I have assumed that erratic peaks and troughs of this nature were a result of "separation" of droplet size classes. However, the same phenomenon was observed when the simulation was re-run using 10 micron increments for size classes between 0 - 200 microns and 20 micron increments for size classes between 200 - 400 microns (above this size, classes of 50 - 100 micron increments were used).
3. Figure 3 shows a comparison of data versus predictions for the mean values for all D8 runs. The conclusions

are similar to (2) above.

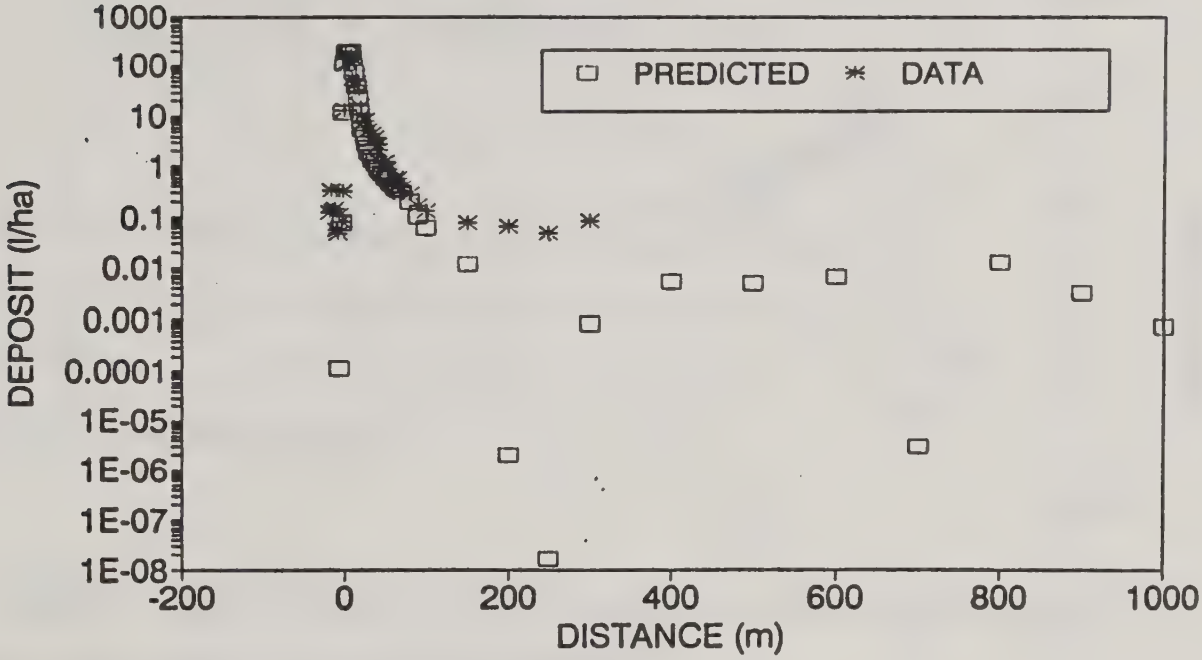


Figure 2: Actual deposit data from Run G (D8) and model predictions to 1000 m downwind.

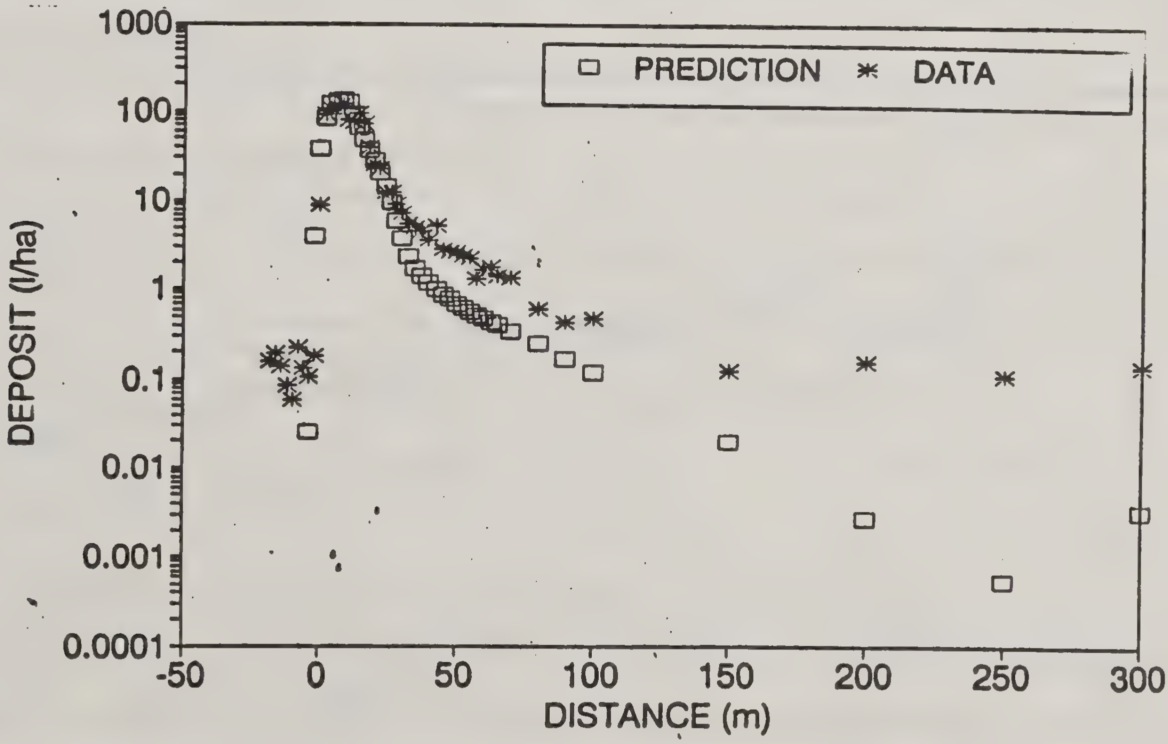


Figure 3: Mean deposit data versus predictions for D8 nozzles.

4. Figure 4 shows a comparison of data versus predictions for the mean values for all D8-45 runs. The match is not as good as with the D8 nozzles, although the general shape of the curve and the position of the peak deposit agree reasonably well. As with the D8 treatment, the model underestimates deposition beyond about

50 m downwind, and there is a large drop-off in predicted deposition at 200 m downwind.

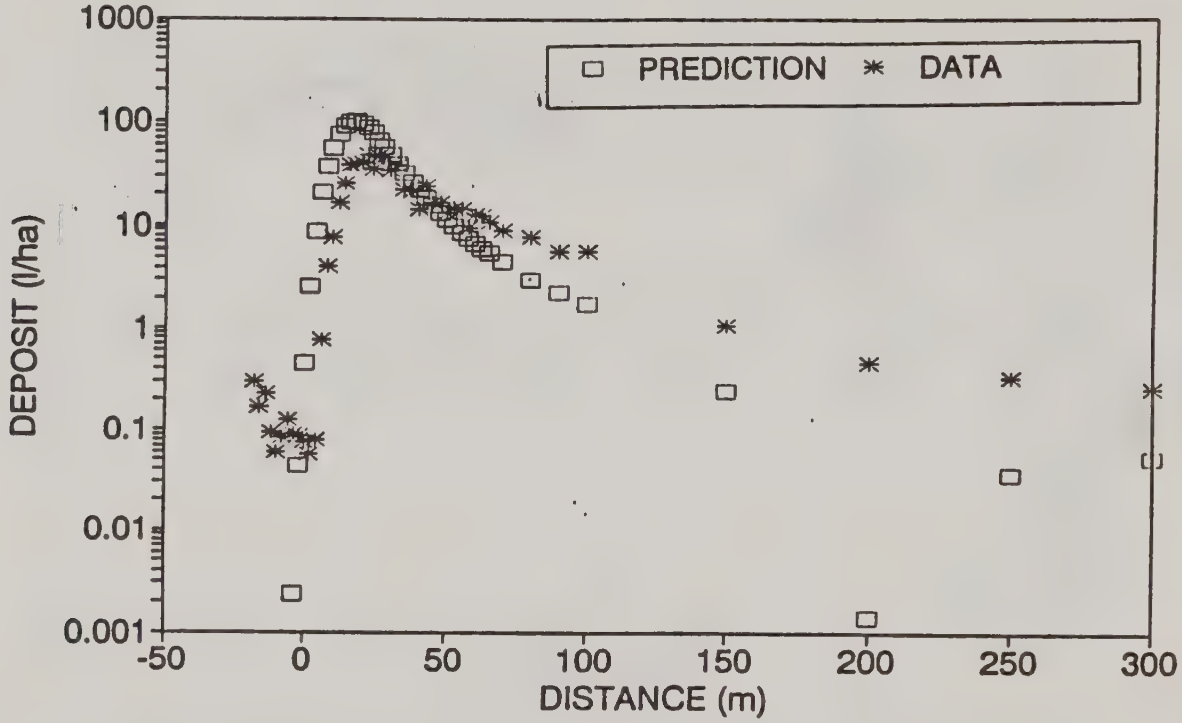


Figure 4: Mean deposit data versus predictions for D8-45 nozzles.

5. The agreement between rotorod data and predictions was generally quite good (Figures 5 and 6), although once again there was some erratic behaviour in the predictions.

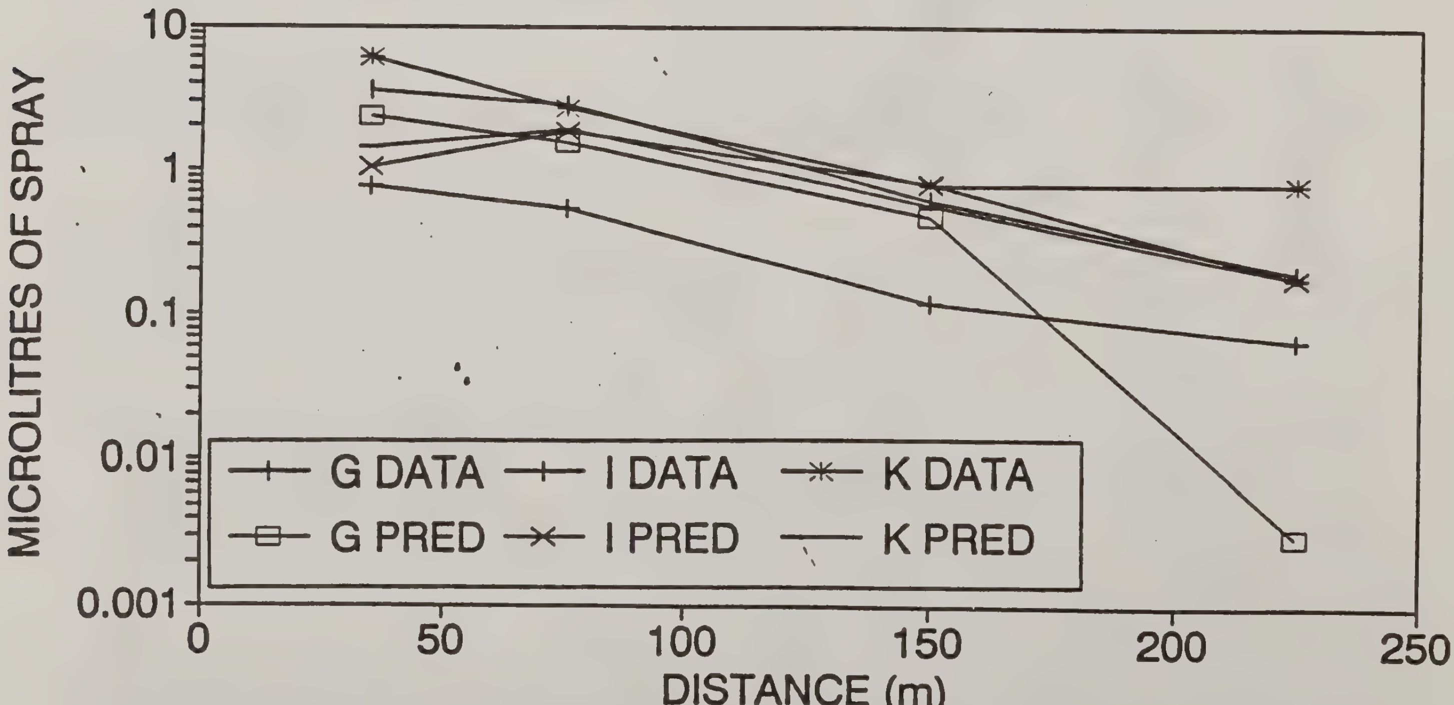


Figure 5: Mean rotorod data versus predictions for D8 nozzles.

FROM WANDLYN NEWCASTLE

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Service de l'environnement atmospherique
Downsview, Ontario, Canada M3H 5T4

TELECOPIER MESSAGE

Date: September 11 1991

TO:

ADDRESSEE'S NAME Jack Barry Please forward immediately

TELEPHONE NUMBER National Spray Model Advisory Committee

FAX NUMBER (703) 552-0827

NUMBER OF PAGES TO FOLLOW 1

FROM:

SENDER'S NAME: Bob Mickle - AES - ARQP, Auberge Wandlyn, Newcastle, New Brunswick

TELEPHONE NUMBER (506) 622-3870 Ext 137 or 163

FAX NUMBER 506-622-3250

CONFIRMATION NO.

REMARKS:

Jack;

Sorry that once again I am unable to attend the NSMAC meeting but events (field work/ airport disruptions) have made it impossible to attend the meeting. With respect to future meetings, I have talked to FPMI about the possibility of holding the next meeting in Sault Ste. Marie, Canada. It would give everyone an opportunity to see the facilities at FPMI during the one or two day meeting. Also the location gives easy access to the border so that participants who have problems making travel arrangements to Canada would be able to stay in the States and commute (30 min) across the border.

We are presently involved in a field project to assess the deposit to natural foliage (raspberry and red maple) as well as to foliage simulators from Cessna Agtrucks spraying with TVB, D8-46 and AU4000. The thrust of the work is to compare the deposit and drift as a function of emission spectra, meteorological variables and operational variables such as aircraft height. This work is a continuation in efforts to make recommendations to aerial applicators on better targeting techniques using more efficacious droplet sizes hence being able to reduce pesticide at the source and reduce ferrying time (ie less cost).

Ultimately the results will be used to validate model predictions of both FSCBG and AgDisp. As with most of these experiments we are attempting to augment the existing data in order to assess model predictions with the view to being able to use models not only for setting up operational sprays but also to assess deposit from the same sprays. As you are aware we are also in the process of evaluating these models to assess their capabilities to be used in the registration of pesticides. Presently we are developing a data base on deposit from aerial/ground applications. I would like to invite contributions from the membership of the NSMAC in the form of reports documenting deposit/drift from spray trials. Each contributor will receive in return a copy (PC diskette) of the complete data base free of charge. Once compiled , this data base will be statistically analysed to establish the important operational variables in determining the ultimate deposit and drift patterns. After this is completed sensitivity runs on the models would be carried out to ensure that they conformed to the results of the statistical analyses. At the same time the models will be directly compared with the absolute deposit measurements to evaluate their capabilities to make absolute predictions. This will of course be difficult to do since several different deposit samplers have been used in the past for which collection efficiencies as a function of drop size may not be known.

I have only had a brief opportunity to evaluate FSCBG. Generally speaking the new version is very user friendly which will add to it's acceptance in the user community. I would like to see a concerted effort go into evaluating the various sub-modules. One of the easiest ways to look at mass consistency is to integrate the deposit (canopy+ground) with the drift transport(dosage*U) at various distances down range to ensure that it is equivalent to the Line Source Strength (gm/m). This is the technique that we use in field experiments in order to ensure that the collection efficiencies are proper, biomass measurements are appropriate and that generally the experiment has been successful. Above I mentioned that we are looking to use models to quickly assess deposit after an operational spray. Presently we are instrumenting spray aircraft to give on line measurements of A/C speed, height above ground, Ta,RH, boom pressures, flows, atomizer RPM and A/C position. From this data it would be useful to quickly (1 day) produce a deposit map of the spray site for say three different wind conditions (light cross and parallel, maximum for spray period). This would require multiple non-parallel lines to be modelled. Variations in height would be modelled as two runs at the two extremes and one at an average height.

Again Jack I'm sorry not to be able to be at the meeting. Certainly the next one if it is held in Sault Stye Marie. I'll be interested in the minutes of the meeting.

Bob Mickle

Dave Miller

6 Sept 1991

Karl,

Here are some thoughts on the status of the FSCBG(PC) model.

1. It is important to remember that the model only predicts the AVERAGE of an ensemble of individual spray applications and that the deposition, location and amount, from an individual spray operation can be expected to vary from the prediction by large amounts.

2. Its performance in our 1988 field comparison was not bad. It's performance in predicting the MEAN deposition distribution of our 17 spray runs was better than current, similar class, air pollution models. That is it consistently underpredicted the amount of deposition by an average of about 50% and was off on the distance of drift of the peak deposition amount by about 100%. These errors are comparable to other air dispersion models.

I think this performance in predicting the AVERAGE spray application can be improved considerably with some minor adjustments to the model formulation, inputs and usage criteria.

3. In its current form the model is most useful as a training tool. One should be cautious about using it to specifically plan individual operations.

4. If the model is to be used to predict AVERAGE drift, I think more basic adjustments need to be made how the model handles the wind, turbulence and stability conditions (both in its formulation and input measurements).

5. If our 1990 data supports these conclusions, and it appears so, I would like to get together with Milt and compare thoughts on how he could make some modifications and how we might go about testing them.

Dave Miller

Dave

United States Department of Agriculture
Agricultural Research Service
Mid South Area
Application Technology Research
P.O. Box 350
Stoneville, Mississippi 38776

August 26, 1991

Dr. John W. Barry
Chairperson
National Spray Model Advisory Committee
USDA-Forest Service
Forest Pest Management - Ste 102
2121 C. Second Street
Davis, California 95616

Dear John:

I accept your invitation to join the National Spray Model Advisory Committee. I regret that I will be unable to attend the meeting in Blacksburg, September 12-13, 1991. However, I do hope to attend the FSCBG workshop in November.

My comments on FSCBG are:

1. A sensitivity analysis of all variables, with emphasis on variables that can be controlled during spraying, such as equipment variables, is strongly needed for fixed-wing ag aircraft (especially Turbo-Thrush and Air Tractor 402 & 502).

2. X-Y plots of deposit versus distance at user selected cross-sections is needed in two ways: 1) to help visualize the continuous nature of the deposit, and 2) to provide a means to compute slope(s) of deposit curves.

3. A simplified variable to express deposition is needed--so that comparisons between variables can be more easily identified. Milt's "Figure of Merit" is a good idea. The notion of a "centroid" of the deposit, or deposit curve slope(s), are other possibilities.

4. Model verification is a continuous process that should be continually addressed.

5. I've been using the older version of FSCBG and understand that version 4.0 has significant improvements in ease of use. Milt also informed me that a few corrections in the computations were incorporated into version 4.0. In light of this, I'll hold a couple of questions until the workshop when I have a chance to use the new version.

Sincerely,

Al Womac

ALVIN R. WOMAC, Ph.D.
Agricultural Engineer

Appendix E

Recent Reports/
Publications

RECENT REPORTS/PUBLICATIONS

1. Teske, Milton E., Kenneth P. Bentson, Roger E. Sandquist, John W. Barry, and Robert B. Ekblad. 1991. Comparison of FSCBG model predictions with Heather Seed Orchard deposition data. J. of Applied Meteorology, 30-9, 1366-1375.

2. FSCBG/AGDISP Model Technology Transfer Letter No. 2. July 24, 1991. USDA Forest Service, 2121 C 2nd Street, Davis, CA 95616.

3. Barry, J.W., R.B. Ekblad, M.E. Teske and P.J. Skyler. 1991. Technology takes flight. Agricultural Engineering, 72(2):8-10.

4. Teske, M.E., J.W. Barry and R.B. Ekblad. 1991. Preliminary sensitivity study of aerial application inputs for FSCBG 4.0. Paper No. 911052. ASAE summer meeting. Albuquerque, NM.

5. Skyler, Patricia J. and John W. Barry. 1991. Final report - compendium of drop size spectra compiled from wind tunnel tests. FPM 90-9. USDA Forest Service, Davis, CA.

6. Teske, M.E. and T.B. Curbishley. 1991. Draft - Forest Service aerial spray computer model FSCBG version 4.0 user manual. Report No. FPM 91-1, also Continuum Dynamics, Inc. Report No. 90-06. USDA Forest Service, Forest Pest Management, Davis, CA.

7. Teske, M.E., T.B. Curbishley, J.W. Barry and R.B. Ekblad. 1991. FSCBG: An aerial spray dispersion model for predicting the fate of released material behind aircraft, Society of Environmental Toxicology and Chemistry (SETAC) annual meeting. Arlington, VA.

8. Teske, M.E., P.J. Skyler and J.W. Barry. 1991. A drop size distribution data base for forest and agricultural spraying: Potential for extended application. Presented at 5th international conference on liquid atomization and spray systems, ICLASS-91. Gaithersburg, MD.

REPORT FOR THE NATIONAL SPRAY MODEL STEERING COMMITTEE

USE OF FSCBG IN NEW ZEALAND

Brian Richardson

RESEARCH

1. Spray drift from orchard airblast sprayers and tree shelter belts as barriers to drift

Earlier this year a trial protocol was developed for measuring spray drift from an orchard airblast sprayer with collaboration between NZ Forest Research Institute (NZ FRI), NZ Agricultural Engineering Institute (NZAEI), and the USDA Forest Service (USDA FS). The substantial input from the USDA FS (via Harold Thistle and Milt Teske) is a result of an increased level of collaboration between the USDA FS and NZ FRI.

The objectives of the trials were to:

- Characterise orchard airblast sprayers.
- Measure the effectiveness of shelterbelts on reducing drift.
- Provide drift data to the USDA Forest Service for further development of FSCBG

An initial trial was completed in early autumn. The basic design was to release spray from an airblast sprayer along a single line, upwind of a shelterbelt. Airborne spray flux and ground deposition were measured both upwind and downwind of the shelterbelt using Rotorods, suction samplers, and steel plates placed on the ground. The shelterbelt was characterised using photographic and video techniques in combination with image analysis, and with the LiCor Plant Canopy Analyser.

The greatest problem (as usual with this type of experiment) was waiting for appropriate meteorological conditions, especially wind direction, before the autumn leaf fall. Although the weather was never ideal, some initial data was successfully gathered and this is currently being processed. The intention is to continue with this collaborative work next summer.

2. Spray deposit variation

Work on the analysis of spray deposit variation following aerial herbicide application in forestry is ongoing (see report submitted at the last meeting). The initial analysis involved the use of field data and model simulations to determine the magnitude of spray deposit variation and important parameters that contribute to this. More recently, information on deposit variation has also been linked to general models of herbicide/weed dose-response and weed/crop competition, so that the cost-benefit of reducing deposit variation (e.g. by using GPS) can be evaluated. Specific data for the dose-response and competition models was of low quality or not available. However, with this approach, a number of scenarios were developed to examine the effect on crop growth of deposit variation in situations with "idealised" weeds of different competitive abilities and using "herbicides" of different effectiveness (see Abstract report).

ECONOMIC AND BIOLOGICAL IMPLICATIONS OF HERBICIDE SPRAY DEPOSIT VARIATION IN FORESTRY

Brian Richardson, Kylie Miller, and John Ray

NZ Forest Research Institute, Private Bag, Rotorua

31.5.94

ABSRACT

To determine the biological implications of herbicide spray deposit variation, models of herbicide deposition were linked to models that describe the response of the weed to the herbicide and the response of the crop to various levels of weed control. In a typical forest herbicide application, less than 20% of the sprayed area is likely to receive a herbicide dose within 10% of the application rate. The average coefficient of variation is 43%, but values higher than 70% have been recorded during operational field trials. The effect on radiata pine growth of these levels of deposit variation was determined assuming a weed species of high or low competitive ability and for a variety of herbicide/weed dose-response curves. In the worst-case scenario (i e. a highly competitive weed species that is very sensitive to the herbicide dose at the nominal application rate) growth losses of 13, 15.5, 17.5, 20.5% were respectively associated with deposit variation levels (coefficient of variations or CVs) of 10, 30, 43, and 70% Thus the greatest effect on growth occurs when the CV of deposition goes from 0 - 10%. It is unrealistic to reduce operational CVs below about 30%, and the growth gain in reducing the level of variation from 43 or 70% to 30% is only 2 and 5%, respectively, at age 2.5 years.

At age 2.5 years, the growth gain in reducing CVs from 70% to 30% is equivalent to a gain in net present value(NPV) of about $/ha 23-25. This calculation assumes that the time advantage at age 2.5 years remains constant until rotation age. In reality, the time advantage would likely to increase with buddleia as a competitor, so these are likely to be minimum values for gain in NPV. The gain in NPV is the amount of money that can be spent on reducing deposit variation within the limits discussed above.

TRAINING AND TECHNOLOGY TRANSFER

1. Course in NZ

In February this year, the second New Zealand FSCBG training course was held at the Forest Research Institute in Rotorua. Ten people attended the course (four forest managers, two researchers, two pilots, and two chemical company representatives) including two from Australia. The course was run over 3 days with instruction from Milt Teske and help from Harold Thistle, John Ray and myself. The course was well received, and its obvious success was, to a large extent, due to the marathon efforts of Milt Teske. The increasingly user-friendly nature of the software was also demonstrated by the fact that even the students with little computer experience soon mastered the basics of FSCBG. A number of "bugs" in the beta 4.3 version were found and a lot of useful suggestions were made by students.

There are now 16 registered FSCBG users in New Zealand. This is probably the highest per capita rate of users anywhere in the world, including the USA. The high level of interest in FSCBG in New Zealand is driven through the forest industry. Plantation forests in New Zealand are highly dependent on intensive management practices, including the application of pesticides, predominantly herbicides. The forest industry has for many years taken initiatives to ensure that they are using the best possible application practices for both environmental and economic reasons, and use of models such as FSCBG is one important approach. The model is being used by the forest industry to provide general guidelines for designing spray operations and for minimising drift.

It is hoped that eventually another course will be held in New Zealand to cater for Australasian needs.

2. Proposal for manual on recommendations for minimising drift

FSCBG is a powerful and increasingly user-friendly tool. In New Zealand, it is used predominantly for issues relating to spray drift. Even though a significant number of people have been trained to use the model it is still not accessible to most. A major concern is that the "knowledge" contained within, or that can be derived from, FSCBG is still not easily available to the spraying community (either managing, regulating or applying sprays). We cannot realistically expect all of the pilots, foresters, contractors etc. who are involved with spraying to learn how to use the model, and to remain sufficiently familiar with it so that they can use it at irregular intervals. It is therefore essential to present this information in another form.

The "What's New in Forest Research" publication, produced by NZ FRI in 1993, is the type of publication required, but this article only presented information on how to reduce drift when there is an extreme drift hazard. There are many instances when these recommendations would not be the best spraying method. A major task over the next 12 months is to develop some other form of publication for transferring the technology and "knowledge" relating to spray drift, embedded in FSCBG. Two main steps are being considered.

1. Development of an easy-to-understand manual with simple diagrams that illustrate the importance of various spray parameters in terms of spray drift. The manual will be developed using data from FSCBG model runs. However, from our experience, general

users find it difficult to interpret graphical representations of spray drift presented using normal methods. For the manual, new forms of presentation have been developed that operational people find easier to understand. The manual will demonstrate the effects of important variables on spray drift and operation productivity and will assist managers to develop appropriate spraying prescriptions.

2. A second step would be to use the information generated from preparing the manual, plus additional FSCBG runs , to produce a more complex, decision support system (DSS). The decision support system would be either presented as computer software or as a book/manual. With this approach, the objective would be to guide managers and operators through the decision making process, helping them select optimal treatments for a given scenario A PC-based DSS to assist with spray application problems would be linked to a Vegetation Management DSS that NZ FRI and its partners have already developed. At present, this system selects the best chemical or non-chemical treatment to manage vegetation on any site, but it has only limited information on herbicide application techniques.

While neither of these approaches can replace FSCBG, it is hoped that they will make information derived from the model more readily available to users.

3. International Conference on Forest Vegetation Management

In March 1995, the NZ FRI is hosting the second International Conference on Forest Vegetation Management (see Jack Barry for more information). One of the three major themes to be addressed is "Regulatory, Training and Management Support Systems". Contributions are invited on topics relating to technical and training issues with FSCBG and associated models, as long as the subject relates to vegetation management issues. For more information, contact either Jack Barry or Brian Richardson.

HERBICIDES USE AND REGULATION IN NEW ZEALAND'S PLANTATION FORESTS

Brian Richardson and John Ray

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SUMMARY

Plantation forests in New Zealand are intensively managed to achieve and sustain high levels of productivity. Broadcast weed control, generally using herbicides, has been a traditional practice to ensure high crop growth rates and survival after planting. More recently, the concept of vegetation management has been adopted and the focus has been on developing regimes of operations to achieve management objectives. These regimes include treatments that add new vegetation (generally grasses and agricultural legumes) to sites, as well as both broadcast and selective weed control using herbicides.

A wide range of herbicides are available for control of woody and herbaceous vegetation in both pre- and post-plant situations. Aerial spraying is still the predominant method of aerial herbicide application, but there is increasing emphasis on selective spot treatments that have the advantages of reduced chemical use, reduced costs, and generally less potential for spray drift. Aerial application simulation models such as FSCBG have an important role in improving the efficiency and reducing the potential for spray drift from aerial herbicide applications. Herbicide selection decision support systems are likely to have an increasing role in helping to optimise the use of herbicides.

Regulation of herbicide use in New Zealand is currently covered by a wide range of laws. However, a process of rationalisation is underway, that will both simplify and tighten up the legislation. The most important new development is the introduction of the Resource Management Act (RMA). Under the RMA there will effectively be three levels at which controls can be set on herbicide use. The Government (Ministry for the Environment) will set the basic rules covering such things as minimum water and air quality standards; Regional Councils (there are 14 Regional Councils covering the whole of New Zealand) must adopt centrally defined standards but are empowered to increase their stringency within their area of control; District Councils (there are several districts within each region) can only increase standards set by their governing regional council. The forest industry has already established a Code of Practice that includes all areas of pesticide use, and requires that all employees involved with any aspect of pesticide use, undergo training.

INTRODUCTION

New Zealand is a land of 26.7 million ha, spanning latitudes of approximately 47° to 34° in the Southern hemisphere. Almost 28% of the land area is covered in forest including 1.2 million hectares of plantations (NZFOA, 1991), the majority being privately owned. Plantation forestry is synonymous with radiata pine (*Pinus radiata* D. Don), which is grown on more than 1.1 million ha of the plantation area. Within the radiata pine forests, high levels of productivity are often achieved and maintained through intensive management practices. Out of these practices, vegetation management plays a critical role in early stand establishment and has a large influence on initial, and sometimes later, growth rates. Following a brief introduction explaining the importance of, and background to vegetation management ipractices this paper presents a detailed discussion on the use of herbicides in New Zealand's plantation forests.

Vegetation management versus weed control

In the past, all vegetation on a site, other than the crop trees, has generally been categorised as undesirable and therefore "weeds". Thus, sophisticated methods of weed control were developed, generally using herbicides, and were applied broadcast (i.e. total weed control) to most sites as a matter of course. However, more recently there has been a philosophical shift in terms of managing non-crop plant species and the mentality of "weed control" has been replaced by the concept of forest **vegetation management**. The original concept of vegetation management was to change the focus from that of simply removing all non-crop species i.e. weed control, to that of reducing the **influence** of weeds (Walstad and Kuch, 1987). With this outcome in mind, the research emphasis must also shift from simply developing tools to remove weeds, to understanding the effects of non-crop vegetation on crop growth and long-term site productivity.

The concept of vegetation management also acknowledges that the focus must be on the development of regimes to manage the site over a long period. A weed control treatment in forestry is always a short term option (non-crop plants will eventually establish and occupy a site unless the treatments are endlessly repeated) therefore emphasis must be on the development of sequences of operations or **regimes** that achieve the ultimate management goals. In practice, vegetation management regimes comprise operations that result in vegetation removal (often selective weed control) and sometimes also vegetation additions. The aim is to manipulate the natural succession of the site so that it follows the most favourable sequence for the management objectives. However, herbicides are still the primary method used in the development of vegetation management regimes.

Why manage vegetation?

There are many reasons, summarised below, why vegetation management is practiced in New Zealand forestry.

1. *Reduce interspecific plant competition*

Many studies have demonstrated large growth gains following removal of plant competitors (Richardson, 1993). Thus, the primary aim of vegetation management is usually to "channel site resources (i.e. light, water, and nutrients) into the crop species rather than non-commercial species" i.e. reduce competition between the trees and the other plant species, to maximise crop growth and survival.

2. *Land clearance*
Prior to the 1970s, most plantations were established on virgin and cutover native forests (Boomsma, 1982), therefore much of the vegetation management was focussed on clearing sites of existing native shrub and hardwood vegetation to allow the planting of tree seedlings. However, more recently the trend has been to establish forests on flatter, more fertile pasture land, and large scale conversion of native forests to plantation forests is rarely practiced (NZFOA, 1991).

3. *Microclimate modification*
Vegetation management is also practised to modify the seedlings' thermal environment. In areas prone to out-of-season frosts, complete vegetation removal is practised for up to 2 years after crop planting to raise the air temperature close to the ground and decrease the likelihood of frost damage to radiata pine (Menzies and Chavasse, 1982).

4. Fire hazard reduction and stand access
Sometimes vegetation management is undertaken for fire prevention or reduction of fire hazard (Burrows et al., 1989) and/or to improve stand access for tending operations such as pruning and thinning (Balneaves, 1981; Zabkiewicz and Balneaves, 1984).

4. *Pre-emptive weed control*
Weed control is sometimes carried out in areas and roadsides adjacent to plantations to prevent the development of future problems from invasive species.

5. *Oversowing*
In contrast to the need for vegetation removal as described above, vegetation management in New Zealand sometimes involves establishing various non-crop plant species. Of particular interest is the establishment of N-fixing species (Gadgil et al., 1984) to improve site/crop nutrition. Other reasons are to provide fodder in agroforestry systems, to establish a "benign" or easily controlled ground cover that will help to exclude more severe woody competitors, and to reduce erosion.

VEGETATION CONTROL USING HERBICIDES

Traditional means of controlling vegetation include the use of chemicals, mechanical treatments, manual cutting, and fire, although there are an increasing number of other options. However, herbicides have by far a dominant role in New Zealand forestry. A detailed discussion of the role of herbicides and regulations governing herbicide use follows. For more information on alternative methods of vegetation control in New Zealand see Richardson (1993).

Results from a recent survey (Boomsma and Hunter, 1990) illustrate the dominant role of herbicide treatments for vegetation management. Many stands have more than one treatment and very few have no herbicide treatment. Although herbicides play a critical role on most sites, the quantity of chemical used has actually dropped over recent years (MacIntyre et al., 1989) probably because of improved spray formulation or application methods (Zabkiewicz, 1992).

Prior to the 1970s commonly used herbicides included phenoxies (2,4-D, 2,4,5-T, MCPA) picloram, and desiccants such as AMS, paraquat, diquat in addition to sodium chlorate (Chavasse, 1976). These chemicals were used in the conversion of indigenous native forests, and to release newly established plantations from a wide range of native and exotic woody species (Boomsma, 1982). In the early 1980s, phenoxies, especially 2,4,5-T were predominant (Turvey, 1984). There was much concern at the withdrawal of 2,4,5-T in the mid-1980s because of its importance to the forest industry, but with suitable additives, other chemicals such as glyphosate, metsulfuron, clopyralid (especially for some legume species) and triclopyr (often in mixture with picloram) have taken over its function. Mixtures of herbicides, such as glyphosate plus metsulfuron are also used. Of particular value has been the development of adjuvants, especially organo-silicones such as Silwet L-77 (Stevens et al., 1988), which increase the uptake and efficacy of certain herbicides into hard-to-kill scrub weeds and some perennial grasses. Of the chemicals most commonly used in woody vegetation management control, only hexazinone, clopyralid and triclopyr (low rates) are suitable for broadcast post-plant treatments over radiata pine (Balneaves and Davenhill, 1990).

By the early 1970s, both soil residual and foliar applied herbicides were commonly used for grass and herbaceous broadleaf competition control (Davenhill, 1971). Herbicides included triazines, dalapon, and amitrole (Preest and Davenhill, 1969; Boomsma and Karjalainen, 1982). Glyphosate, available in the 1970s, proved to be excellent for grass control, and hexazinone provided good control of grass and perennial pasture weeds such as sorrel, paspalum, and cat's ear (Boomsma, 1982). Haloxyfop and quizalofop-p-ethyl are useful for selective grass control, including pampas, and clopyralid for broadleaf and herbaceous legume control with terbuthylazine a useful addition for residual activity. Radiata pine is tolerant to most of these chemicals, which can be used in both pre- and post-plant situations, with the notable exception of glyphosate. However, glyphosate has been used in releasing situations using a knapsack sprayer to kill vegetation surrounding the seedlings.

To help managers select the most cost-effective and safe herbicide for each situation a PC based Vegetation Management Decision Support System has been developed (Mason, 1991; Mason et al., 1992). The first version was purely a herbicide selection system; however, the most recent version incorporated non-chemical weed control methods. The ultimate goal is to have the system select the optimum sequence of treatments (i.e. the regime) necessary to meet the management objective.

To summarise, chemical weed control has proven to be economic, it can be applied on rough, steep terrain using aircraft, and produces large growth responses (Boomsma, 1982). Because of environmental concerns however, there is continued pressure to seek alternatives and reduce reliance on chemicals. Although herbicides are extremely important to successful forest establishment and early growth, vegetation must usually be controlled as part of a regime of which herbicides are only one component. More information on herbicide use and weed control in New Zealand plantation forests is available in a recent publication (Davenhill et al., 1994).

HERBICIDE APPLICATION METHODS

Aerial application

Aerial herbicide application in New Zealand was becoming popular by the mid-1950s, (Currie, 1959). At this time, environmental issues and concerns did not occupy the prominent position they do today. Nevertheless, spray drift from herbicides was regarded as a real concern. Ferens (1955) noted that,

"... these chemicals in the wrong hands or with incorrect application can be dangerous; the avoidance of light winds is essential for both good control and for reducing the damage to neighbouring properties. Damage has been reported as much as 15 miles from the site of spraying in unfavourable conditions."

Today, aerial application is the most extensively used method of herbicide spraying in New Zealand (Turvey, 1984). This technique has advantages of high productivity (area sprayed per hour) even on steep, broken, slash-covered terrain, inaccessible to ground sprayers. Helicopters are used almost exclusively, the Bell Jet Ranger being most common, and smaller numbers of others including Hughes 300 and 500, Hiller 12E, Aerospatiale Lama and Squirrel. Advantages of helicopters over fixed wing aircraft are that they are more precise in steep, broken terrain, they can fly slower and lower, and can follow contours more readily (Ray, et al., 1992). Although more expensive per hour, helicopters can be more productive than fixed wing aircraft of comparable size, depending on factors such as relative load capacity, location of helipad/landing strip, application rate (Ray, et al., 1992).

Drift reduction is always a major concern and as such, sprays are generally applied using what are considered to be "low-drift" nozzles. Because of the large droplets produced by most low-drift nozzles, there has always been the trend to use high application volumes (usually between 200-350 litres/ha) to ensure good coverage is achieved on hard-to-kill brush weeds. However, over recent years there has been a gradual trend towards lower spray volumes (generally between 50-150 litre/ha). Although this gives a reduction in spray coverage on the target plant, superior chemicals and adjuvants clearly compensate for this factor, and there is the added benefit of increased productivity (area sprayed per hour). In terms of hectares of forest land sprayed, foaming nozzles are probably the most common nozzle, followed by conventional D8-45 nozzles and then D8-46 nozzles. Results of recent trials have confirmed that foaming nozzles significantly reduce drift potential compared to the D8-45, so it is likely that they will continue to be used. However, in situations where drift control is paramount, nozzles which will reduce drift even further would include D8 straight back or Raindrop (Delevan Co.) nozzles. The half-overlap flying technique is generally used to reduce coefficients of variation. On flat sites, some form of flight line marking (e.g. flagmen) is not uncommon, but this is often impractical on steeper terrain. The potential of GPS as an electronic aid to increase the precision of herbicide applications is under investigation.

To identify techniques to minimise herbicide spray drift, a considerable effort has gone into applying and validating the FSCBG spray application simulation model (Teske et al., 1993) to New Zealand conditions. The model has been used to provide general recommendations for minimising spray drift, and for selecting spray equipment and methods for maximising productivity. It has proven to be an excellent training tool (there are 16 trained users in New Zealand, with a further two from Australia having been through the New Zealand training

course), and it is hoped that using the model operationally will be accepted by regulators as evidence of applying "best practices".

Ground application

On flatter terrain, largely free from logging slash and with easy access, ground based herbicide application techniques using vehicle-drawn booms or hand-held sprayers are viable methods, particularly on smaller blocks. Vehicle mounted boom sprayers treat 1-2 m wide strips along planting lines (Flinn and Fagg, 1984; Balneaves, 1987). Spot treatments reduce costs still further (Davenhill, 1988; Davenhill et al., 1992; Flinn and Fagg, 1984; Glass, 1985) and also have the advantages of reduced environmental impact and less drift, particularly with the use of granules. "Spots" usually comprise circles of radius 0.5 - 0.6 m centred on each young tree that is treated. Originally, herbicide spot treatments were applied with knapsack sprayers (Davenhill et al., 1992), but these have largely been replaced with "spot guns" (Porter, 1979). More recently, the "Weed-a-Metre" has been developed for spot-application of herbicide granules (Davenhill et al., 1992). Although granular herbicide formulations are more expensive, the Weed-a-Metre has the advantage over spot guns in terms of higher productivity (Davenhill and Hall, 1988), lighter weight, and no water or chemical mixing is required. The area of forest land suitable for spot applications is increasing with the trend towards oversowing forest sites to provide an herbaceous (grass and broadleaves) ground cover, consequently the importance and interest in this method of application has also increased.

LEGISLATION COVERING THE USE OF HERBICIDES

At present, there is a bewildering array of Acts and regulations covering different aspects of pesticide use in New Zealand. However, with the introduction of the Resource Management Act (RMA) in 1991, a process of rationalisation has begun. Pesticide regulations will soon be covered by fewer pieces of legislation and will be much stricter than previously. Although this reorganisation is not completed and many of the old laws are still in place, the following summary focuses mainly on the RMA because of its future central role in pesticide legislation.

Resource Management Act

The broad purpose of the RMA is to promote the sustainable management of natural and physical resources. "Sustainable management" means managing the use, development, and protection of natural and physical resources in a way, or at a rate, which enables peoples and communities to provide for their social, economic, and cultural well-being and for their health and safety while-

(a) Sustaining the potential of natural and physical resources (excluding minerals) to meet the reasonably foreseeable needs of future generations; and

(b) Safeguarding the life-supporting capacity of air, water, soil, and ecosystems; and

(c) Avoiding, remedying, or mitigating any adverse effects of activities on the environment.

This Act has widespread implications for many aspects of forestry including herbicide use. The RMA specifically prohibits the discharge of contaminants into water, or onto ground in such a way that the contaminant or its breakdown product enter water. Contaminants can be discharged with the appropriate consent but this would never be given for pesticides. There is provision in the Act for pesticides to be applied over "productive land", provided that pesticide application is not specifically prohibited in the Regional Plan (see below for explanation of Regional plan). Included in the RMA is provision to establish a Hazards Control Commission which will operate under the Hazardous Substances and New Organisms Act. This legislation, which was to be introduced in 1993, will ultimately replace existing acts and regulations governing the use of pesticides. Due to the complexity of preparing this piece of legislation, the 1993 deadline has not been met!

The RMA allows for controls to be imposed at three levels;

(a) **The Government** (Ministry for the Environment) will set the basic rules governing such things as minimum water and air quality standards (the RMA provides powers to control the discharge of hazardous substances into air , soil, and water).

(b) **Regional Councils** (there are 14 Regional Councils covering the whole of New Zealand) must adopt centrally defined standards, but are empowered to increase their stringency within their area of control. Regional Councils are responsible for law enforcement.

(c) **District Councils** (there are several districts within each region) also can only increase standards set by their governing regional council.

Regional and district councils are required to produce plans for their areas and have the power to restrict or even prohibit the use of any, or specific pesticides within certain areas. Zoning may prove to be the most effective mechanism for isolating pesticide application from the general population. The Act does not restrict pesticides to agricultural or horticultural land, but does prohibit their use in a way that would contaminate water. The councils are also responsible for the enforcement of regulations. Individuals or groups can apply for an abatement order if the discharge/application is deemed to be "noxious, dangerous, offensive, or objectionable to such an extent that it has, or is likely to have, an adverse effect on the environment". This provision seems to provide a means of possibly restricting the use of pesticides, as many will have an adverse effect on at least some part of the environment. Abatement orders do have the potential to restrict the use of pesticides, but if the use is included in the regional or district plan it may not be so easy to stop.

The New Zealand forest industries response to the Act has been to liaise with regional and district councils at the stage of plan development in an effort to make planners aware of how and why pesticides are used, the quantities applied, and the precautions taken to limit adverse

effects both on and off site. This approach seems to have been successful and it is likely that the councils will take a "best practices" approach, rather than specify clearly defined limitations on application methods. In addition, the forest industry has voluntarily developed a Code of Practice for the use of pesticides and is ensuring that its staff are fully trained. The conditions set out in the Code of Practice are not mandatory but there is a precedent in New Zealand law to incorporate a code or parts of it in regulations to make it mandatory. Alternatively, the Regional Council could include the Code or parts of it in its Regional Plan and compliance with those sections would again become mandatory.

Other considerations

Another recent law with major implications for the forest industry is the Health and Safety in Employment Act of 1992. This requires all employers to identify all hazards associated with any particular operation and then eliminate, isolate or minimise the hazard. It requires the employer to notify employees of the hazards and to provide the appropriate safety equipment/clothing and training to enable them to carry out the operation safely. The employee must use the safety equipment provided. Failure by either parties to fulfil their obligation under the Act, render both liable to heavy penalties. Once again, the response of the forest industry to this Act has been to place an increased reliance on training all employees and contractors to a national certification standard and to ensure good supervision is available.

The regulatory emphasis has, to date, focussed on voluntary observation of standards of good practice. However in a recent report to the Parliamentary Commissioner for the Environment entitled "Management of Agrichemical Spray Drift" it was recommended that:

(a) a compulsory system of registration and training of applicators should be established
(b) codes of practice should become mandatory
(c) minimum standards for equipment should be set
(d) records should be kept of pesticide misadventure with the power to deregister applicators if it is shown that they have failed to follow the code of practice.

If these recommendations are accepted and incorporated into law, they should not have a big impact on the forest industry because they have essentially already implemented these measures.

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NATIONAL SPRAY MODEL AND APPLICATION TECHNOLOGY STEERING COMMITTEE

Kansas City, MO, June 22 1994

Summary - The Potential for FSCBG Validation - Australia

Nicholas Woods
Director
The Centre for Pesticide Application & Safety
The University of Queensland Gatton College

The Centre for Pesticide Application & Safety is a national scientific research and training group located at the University of Queensland Gatton College, near Brisbane Australia, which provides a wide range of research and consultancy services to industry and government in pesticide application technology. Equipped with a wide selection of specialist sampling and analytical equipment, research and training support programmes are provided in agriculture, public health (eg mosquito control) and forestry.

A major national research programme is currently underway in Australia entitled "Minimising the Impact of Pesticides in the Riverine Environment Using the Cotton Industry as a Model." Within this programme the Centre has the responsibility for investigating the aerial transport of pesticides in the cotton industry. In particular the ULV and LV aerial application of endosulfan is being targeted. The programme which commenced during the 93/94 growing season has the following components:

- An aircraft testing and calibration phase: Both Turbine and piston engined aircraft are being pattern tested using artificial targets and cotton canopies

- Nozzle performance: The droplet size generated by nominated cotton insecticides is being determined in the laboratory using Malvern 2600 laser diffraction equipment. The performance of Micronair and selected hydraulic nozzles is being evaluated.

- Volatilisation: Post application volatilisation and deposition in water is being assessed using a series of water filled trays and air samplers placed strategically around commercial cotton fields to quantify residue levels.

- Field measurement of pesticide recovery: Using mobile drift measuring towers, fluorometry and gas chromatography, profiles of spray deposits moving away from both commercial spray activities and from controlled experiments are being measured. Deposit curves from single passes of aircraft have been measured in the canopy and from artificial targets. Towers and wires have been used to quantify drift at short and medium distances (up to 600 metres)

The data base being collated will be analysed and tested against models such as FSCBG. Within 3 years the project aims to provide management strategies to industry to enable productive and sustainable cotton production in the riverine environment.

Of interest to the Centre is work being undertaken elsewhere to evaluate FSCBG in field crop canopies such as cotton and the model's sensitivity to describing the performance of ULV pesticides. The data being collected in the Australian aerial application programme should allow some detailed validation of the models.

The future of aerial application technology in Australia will depend in part on the success of this programme. Linkage of simulation models with DGPS systems and computer support spray management packages is being canvassed.

In other research, the coverage and drift profile of orchard sprayers is being determined. The applicability of FSCGB in such scenarios deserves investigation.

Finally there are increasing pressures to use models such as FSCBG in evaluating spray drift occurrences and damage. Comments from the committee on the scientific and legal implications of this trend would be valued.

THE CENTRE FOR PESTICIDE APPLICATION & SAFETY C-PAS

THE UNIVERSITY OF QUEENSLAND GATTON COLLEGE

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- PESKEM® PC for Windows™
- Consultancy & Advice

Contact the Centre if you have any application technology related questions or require any further information on the wide range of services available.

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THE CENTRE FOR PESTICIDE APPLICATION & SAFETY C-PAS

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INFORMATION BROCHURE and SERVICE DIRECTORY

Your guide to consultancy services in Pesticide Application Technology

The Centre for Pesticide Application & Safety (C-PAS)

The University of Queensland Gatton College

The Centre for Pesticide Application and Safety is a national scientific research and training group located at the University of Queensland Gatton College, near Brisbane, which provides a wide range of research and consultancy services to industry and government in pesticide application technology. The Centre comprises of some ten staff made up of research, extension and technical officers from the University and the Queensland Department of Primary Industries.

Equipped with a wide range of specialist sampling and analytical equipment and utilising facilities located at Gatton College, research and training support programmes are provided in agriculture, public health (eg mosquito control) and forestry.

Typical services available include:-

(1) Testing and **calibration of agricultural aircraft**, (encompassing application of both solid and liquid products).
(a) Equipment evaluation (incl. DGPS) and drift analysis
(b) Provision of fully serviced calibration analysis.
Test kits are now available.
(2) Comparative evaluation of **ground rig boom and orchard** spray equipment.
(3) Spray nozzle testing and **droplet size measurement** in the laboratory and under field conditions using a Malvern 2600 laser diffraction analyser.
(4) Assessment of **pesticide recovery** on artificial surfaces such as water sensitive cards
(5) Field studies
(a) establishing the behaviour of agricultural chemical and biological products
(b) researching factors which maximise canopy coverage and **minimise pesticide spray drift.**
(6) The physical analysis of agrochemical formulations and laboratory **rain fastness evaluation.**
(7) The training of personnel in the correct and safe handling, application and distribution of agricultural and public health pesticides through the medium of training **workshops, short courses and seminars**.
(8) Production and maintenance of PESKEM® and now **PESKEM® PC for Windows™**, a national database providing information on all registered pesticides in Australia.
(9) The use and running of pesticide **(drift) simulation models** such as FSCBG.
(10) Publication of industry training technical manuals.
(11) **Consultancy.** The Centre provides specific information and advice on pesticide application and plant protection related matters.

Appendix D

Report - Sub-committee on Meteorology

May 17, 1994

To:

Members of the National Spray Model and Spray Technology Meteorological Sub-committee

Dear Colleagues;

I hope Spring finds you all well. We have had some changes in the organization of this sub-committee since we were together last June in Spokane, WA. Dave Whiteman has resigned the chairmanship of this sub-committee and is off to a sabbatical in Switzerland as of this July. I have been appointed his successor as chairman. Also, Bob Ekblad has retired from federal service and resigned his place on the committee. He is occasionally in touch from his orchard on the lake. On the other side of the coin, I would like to welcome Bob Sanderson of New Mexico State University. I invited Bob to join the committee last week and he has accepted.

While you all have been hibernating over the winter, Dave Whiteman and myself have put together the enclosed rough draft of 'Meteorological Measurements for Spray Drift Modeling'. Please review and return comments to me by August 31. In my opinion, there are three primary concerns regarding this document:

1) I have asked Jack Barry to comment regarding the technical level of this document with respect to the target audience.

2) The document needs illustrations.

3) Are the document scope and subject matter appropriate?

I would appreciate comments on all of these matters as well as a general review. I hope to see many of you in Kansas City in June and we can discuss questions and comments at that time. Otherwise, feel free to call me at 406-329-3981.

Sincerely,

Harold Thistle

DRAFT REPORT

METEOROLOGICAL MEASUREMENTS FOR SPRAY DRIFT MODELING

National Spray Model Advisory Committee
Meteorological Subcommittee

Subcommittee Members:

Dave Miller
Jim Rafferty
Robert Sanderson
Harold Thistle, Chairman
Dave Whiteman

May 17, 1994

OUTLINE

METEOROLOGICAL MEASUREMENTS FOR SPRAY DRIFT MODELING

Meteorological Subcommittee
National Steering Committee - Spray Modeling

1.0 INTRODUCTION

This document provides information on the meteorological measurements needed to run FSCBG, AGDISP and VALDRIFT, three atmospheric dispersion models used to calculate deposition and drift of pesticides from aerial spraying applications.

The report begins with a discussion of the various uses of aerial spray application models, and a description of the three models currently in use. This is followed by a listing of the meteorological measurements needed to apply these models to actual spraying applications, as obtained from the model user manuals. The types of measurements, their frequency, and the number of locations at which the data are needed depends on the purpose of the model application and the particular topography. Several different spraying scenarios are therefore discussed. These scenarios include a small-scale pesticide application in a remote area, a routine pesticide application in an accessible forested area, and a research application. Siting and frequency considerations are then discussed, and illustrated with some sample data sets. Anticipated changes in technology that will lead to new meteorological tools are then discussed. Conclusions and recommendations make up the final section of the report.

2.0 The Spray Models

2.1 Uses of Spray Models

2.1.1 Planning of Operations

Spray models can be used before a field spraying campaign to help with the planning of the field operation, to anticipate operational problems, or to take advantage of special opportunities that will expedite or improve the execution of the spraying campaign.

2.1.2 Operational Decisions

During the spraying campaign, spray models and the real-time meteorological data that drive them can be used to help the on-site spray manager make informed operational decisions. Such decisions include go/no go decisions, determination of the times of initiation and cessation of spraying, and the positioning of equipment and personnel. The data and models can also be used to support operational decisions regarding use of contract spray aircraft and personnel.

2.1.3 Analyze Deposition/Drift

After (or during) the spraying operation the models can be used to estimate the deposition of pesticide on the target area and the transport and deposition of spray onto non-target areas.

2.2 Model Descriptions

2.2.1 FSCBG

The Forest Service Cramer-Barry-Grim (FSCBG) computer model has been developed to allow computer simulations of aerial spraying operations. The model is based on dispersion models originally developed by the U.S. Army ( ). For the past 15 years, the USDA Forest Service has been improving the model for applications in the aerial application of pesticides. The model consists of near-wake transport based on the solutions to aircraft wake vorticity equations (as developed in AGDISP, Section 2.2.2) and a meso-scale dispersion model based on a Gaussian line source approach. The model calculates deposition, canopy penetration and atmospheric concentration. Over the past few years, the FS and Pacific Northwest Laboratories (PNL) have been working on an algorithm to predict the atmospheric transport of aerial sprays in mountain valleys (VALDRIFT, Section 2.2.3). This model should be fully integrated into FSCBG by 1995.

2.2.2 AGDISP

The AGDISP (Agricultural Dispersal) code predicts, as a function of time, the path of material released from a helicopter or fixed-wing aircraft, and deposited on the ground or in a canopy (Bilanin et al., 1989; Teske, 19). To do this, the code tracks groups of similar sized particles or droplets released by the traveling aircraft. The turbulent dispersion of droplets is computed as the group of droplets descends toward the ground, taking account of transport and diffusion in the aircraft wake vortices.

2.2.3 VALDRIFT

The VALDRIFT (Valley Drift) model is an atmospheric transport and diffusion model for use in well-defined mountain valleys (Allwine et al., 1993). It was developed especially for determining the extent of drift from USDA Forest Service aerial pesticide spraying activities. The model is phenomenological - that is, the dominant meteorological processes governing the behavior of the valley atmosphere are formulated explicitly in the model, although in a highly parametrized fashion. The key meteorological processes that can be treated are 1) nonsteady and nonhomogeneous along-valley winds and turbulent diffusivities, 2) convective boundary layer growth and inversion descent following sunrise, 3) cross-valley circulations, tributary flows and subsidence, and 4) interactions with above-ridgetop winds. The model is applicable under relatively cloud-free, undisturbed synoptic conditions and is configured to operate through at least one diurnal cycle for a single valley. The inputs required are the valley physical characteristics, the release rate as a function of time and space, the along-valley wind speed as a function of time and space, temperature inversion characteristics at sunrise, and sensible heat flux as a function of time following sunrise. Default values are provided for certain inputs in the absence of detailed observations. The outputs are air concentrations and deposition fields as functions of time and space.

3.0 Meteorological Measurements to Support the Models

Following is a review of the meteorological data that are currently needed as inputs to the three models.

3.1 FSCBG Model

The following table provides a listing of the meteorological measurements needed to drive the FSCBG model, and the equipment that could be used to make the required measurements.

MEASUREMENTS NEEDED	POSSIBLE EQUIPMENT
Profile inputs	
temperature and relative humidity	tethersonde, airsonde, radiosonde, surface measurements and log extrapolation
wind direction and speed	tethersonde, tracked airsonde, rawinsonde, Doppler sodar, surface measurements and log extrapolation
mixing depth	from equipment above
Single inputs	
net radiation	net radiometer, pyranometer
cloud cover	airways observations, net radiometer, pyranometer
pressure	pressure sensor, barograph
wind direction standard deviation	wind set
Miscellaneous inputs	
global radiation (direct + diffuse)	pyranometer

Table Notes:

• Radar profiler/RASS (Radar Acoustic Sounding System) could measure wind and temperature profiles continuously, but is blind for the first 150 m of elevation and is expensive. RASS provides temperature soundings to heights of about 600-800 m, with limited height resolution.

• Doppler sodars and tethersondes often cannot sound deeply enough to measure mixing depth during summer. Also, many current sodars do not provide information at low enough heights to be of use in meteorological monitoring of aerial spray operations. Mini-sodars are available, however, that can measure winds through depths of 100m with resolution of approximarely 10m. Tethersondes cannot be used in strong winds.

• Net radiometers with rigid domes would be preferable the the ones that have to be inflated with dry nitrogen.

• Cloud cover observations are available from some airports during hours of operation and from certain National Weather Service and Federal Aviation Administration facilities. Net radiometers/pyranometers or on-site cloud observations are possible backups.

• Silicon cell pyranometers are recommended, as they are inexpensive and require little maintenance.

Discussion:

The profile inputs for FSCBG are somewhat simpler than might be implied by the table entries. The model converts the temperature and relative humidity profile data to two constant values, one above and one below the canopy. Only two values are really necessary, one just below the canopy top and one at aircraft height. The model also cannot use more than one wind direction and it uses the wind direction from the highest elevation reported. The height of the aircraft would probably be the most appropriate level. Furthermore, the model is insensitive to actual mixing layer depth so long as it is greater than several hundred meters and the spray is released near the top of the canopy. The mixing layer depth therefore needs to be measured only during the morning transition period. On the other hand, the morning transition period is the preferred time for most forest aerial spraying operations.

The model is sensitive to pressure, so that pressure data are required. The net radiation measurements should ideally be made over the forest canopy, as they are used to estimate atmospheric stability and must take account of cloudiness.

Net radiation measurements taken within the canopy are generally not representative of the above-canopy radiation. In the absence of a net radiometer, an inexpensive pyranometer could be used for this purpose, as methods are available to estimate net radiation from measurements of incoming solar radiation.

A wind profile is needed from the ground to the aircraft altitude (i.e., 0 to 50-100 m above the canopy). Ascending non-tethered sondes rise too quickly through this shallow layer and sample only a near-instantaneous wind speed profile. The desired sounding is a mean wind speed profile.

3.2 AGDISP Model

The only additional input parameter required by the AGDISP model is the Richardson number. This can be determined from the same wind and temperature profiles specified for FSCBG.

3.3 VALDRIFT Model

The VALDRIFT model is a spray drift model for use in well-defined valleys on relatively undisturbed days when winds within the valley are locally driven. It requires wind data from one or more sites within the valley as a function of time. Either surface or vertical wind profile data can be assimilated into the model, as available. The model also uses a pre-sunrise temperature sounding, if available, through the valley depth, and an estimate of the fraction of incoming solar radiation that will be converted to sensible heat flux (i.e., a parameterized surface energy budget). It also needs surface temperature and pressure data. The wind and temperature profiles and other data are already specified for FSCBG, except for the surface energy budget fraction. Since VALDRIFT is a spray drift model and makes calculations far downwind of the spray block, the model calculations benefit greatly from additional wind measurement sites along the drift path, especially vertical wind profile data.

4.0 SEVERAL SPRAYING SCENARIOS

Several types of spraying application experiments could be conducted. Since the meteorological data necessary to support an experiment depends strongly on the experiment design we will illustrate the choice of meteorological measurements for three spray scenarios. The scenarios are chosen to represent three differing scales of experiments needing increasing levels of meteorological support.

For all three scenarios it is assumed that basic weather forecasting support would come from the closest National Weather Service Forecast Office, and that

+ on-site meteorological support should be focused on assisting the on-site manager to make informed application decisions in real time,

+ the on-site data set should be sufficient to document the occurrence/non-occurrence of pesticide deposition in the forest canopy to verify that the spray block was sprayed as desired, and

+ the on-site data set should be sufficient to document the occurrence/non-occurrence of pesticide drift and information on the direction of drift.

4.1 Scenario 1 - <u>A Small-Scale Pesticide Application in a Remote Area</u>

A small-scale pesticide apllication in a remote area requires the smallest amount of meteorological support. The on-site meteorological equipment for this application should be lightweight, portable, battery-operated, easy to assemble and disassemble, and should use radio communications, so as to provide the on-site manager with real time data.

4.2 Scenario 2 – <u>A Routine Pesticide Application in an Accessible Forested Area</u>

A medium-scale pesticide appplication in a non-remote forested area with normal access requires intermediate levels of meteorological support. We will assume that the spray block is accessible and consider the possibiity of using meteorological support equipment that can run off 115 VAC power (either from standard line power or gasoline-powered generators), and that can be transmitted by phone or radio to a fixed or portable operations center for real time use by the operational manager. The meteorological equipment to be used should still be portable rather than fixed, but could be moved by truck - or by helicopter, if necessary.

4.3 Scenario 3 – A Pesticide Spray Experiment with Research Goals

This experiment might be focused on the evaluation of a specific aspect of one of the models, such as canopy penetration, pesticide drift, dispersion in the aircraft wake, effect of cross winds on deposition, etc. The meteorological support for such experiments would need to be designed on an individual experiment basis and the location of the experiment would likely be chosen to maximize access and provide the supporting infrastructure to obtain needed data with new research instruments. Such experiments are costly and opportunities for sharing the costs through collaboration with other agencies or organizations should be investigated, when possible.

5.0 SITING AND FREQUENCY CONSIDERATIONS

The proper siting of meteorological measurement equipment can be a difficult problem, but must be addressed if suitable meteorological data support is to be obtained. A meteorologist with experience in siting of field equipment should be involved in the experiment planning, if possible.

5.1 Sampling Frequency and Duration - General Considerations

Sampling frequency of meteorological parameters in a given monitoring program varies over a wide range depending on the objectives and available resources of the program. Atmospheric turbulence data are frequently collected at rates up to 100 Hz, while some upper air data are routinely collected only twice per day (i.e., .00002 Hz). Typical sampling frequencies for meteorological data in support of aerial spraying will usually fall somewhere between these two extremes with the design dictated by two basic considerations:

1) Low frequency information can be derived from high frequency information but high frequency information can only, at best, be approximated from low frequency information and often is not available at all.

2) The cost of instrumentation, data loggers, data processing and analyses increase with increasing sampling frequency.

The first factor would suggest that high frequency sampling is preferable but the second factor indicates that cost and logistics must also play a role.

The primary control on sampling rate is the data logger and associated storage device. Modern data logging equipment should be capable of almost any reasonable logging rate. Since 1980, commercially available logging rates have increased by at least three orders of magnitude. Where 10KHz analog to digital (A/D) conversion boards were considered fast in 1980, 1MHz is possible today. There are, however, still various constraints associated with data loggers. The total rate must be divided by the number of channels, so that a 100KHz data logger will sample at 1KHz per channel over 100 channels. There is often 'overhead' associated with storing data, so that the logger may be slowed further by data storage requirements, especially if it is operated near capacity. Perhaps the most common limitation encountered with modern systems is the size of the associated storage device. Even a 1 megabyte storage

device can only store 1000 seconds of data when data are sampled at 1KHz.

There are hundreds of companies that manufacture and/or develop data loggers. Data Translation, Inc. and Strawberry Tree, Inc. are examples of companies specializing in A/D boards. LabTech Notebook, Inc. is a software company that develops user friendly software interfaces for use with most A/D equipment. Campbell Scientific, Inc. is an example of a company that designs complete, integrated meteorological monitoring systems including dedicated data loggers, meteorological instrumentation, logging software and radio and telephone communications hardware.

The sampling rate should be selected after considering the response time of the sensor being sampled. The time response is defined as the time it takes for an instrument to achieve two-thirds of full response of a step change in the parameter being measured. For example, if the temperature instantly changed from 0 to 10 degrees C, the time response of a thermometer measuring the change would be the time required for the thermometer to reach 6.66 degrees C. If the sampling rate is higher than the instrument response time, instrument characteristics are being measured rather than atmospheric changes. However, considering 1) above, the atmospheric information can be recovered at frequencies lower than the instrument response.

The nature of the actual signal from the transducer is also a consideration in sampling design. For instance, a common method of measuring wind speed is to attach a magnet to a set of cups which spin at a speed proportional to the wind moving past them. As the magnet turns, an inducted voltage is measured, which changes sign relative to its position in the magnetic field. Thus, one cycle is produced for every turn of the anemometer cups. Typically this type of instrument will be associated with a counter that electronically stores one count for every cycle. The signal from the counter is effectively digital or increments in a discrete step. If the cups turn one revolution for every 6m of fluid passage and the wind is blowing at 1m/s, the counter will only increment once every 6 secs. If the counter is sampled at 10Hz, 60 samples will be collected without any new information.

Finally, the variability of the parameter being monitored and the physical question that is being addressed must be considered. A typical spray swath may take from 10 seconds to 10 minutes or longer to complete. Therefore, atmospheric information is desired that would allow you to distinguish changes occurring inside these time frames. Wind speed and

wind direction can vary significantly over a ten minute period. If coverage or efficacy is different over different areas of the spray block, it is useful to correlate the time of spraying over the different areas with the ambient conditions. If only one average number is available for the duration of the spray period, the time and magnitude of interperiod variation cannot be discerned (see 1) above). Also, in dispersion modeling, the variance of wind speed and direction in particular (and the other measured parameters to a lesser degree) are often of fundamental significance. Due to statistical considerations which are beyond the scope of this document (see Priestly, 1983 for a complete discussion), the variance is more accurately discerned when calculated from higher frequency data.

Sampling duration is typically a straightforward problem. If the duration of spraying on a given day is anticipated to last 5 hours, it is useful to sample for two hours before and 1 hour or so after spraying stops to have a record in case precedent or antecedent conditions influence the program. Duration multiplied by sampling frequency summed over all the sampling channels will determine the size of the data set being stored and should be calculated beforehand to guarantee that sufficient storage is available. Storage capacity is typically expressed in bytes, so a knowledge of the number of bytes involved in individual data parcels allows an exact calculation of storage needs. (Occasionally, storage capacity will be stated in either bits or words. For a discussion of these terms, see .) There are scientific questions about such things as persistence in the environment or recirculation of aerially released material in the atmosphere which may require an alternate basis for the determination of sampling duration.

5.2 Guidance on Sampling Frequencies

The following section is intended as guidance to managers when designing meteorological monitoring for aerial spray operations. Meteorological researchers will obviously be guided by the considerations indicated above as well as their own experience, equipment and objectives. The section is intended to give order of magnitude sampling rates for typical equipment encountered in this type of monitoring.

20 Hz - Most commonly used for high frequency turbulence and turbulent flux sensors (more typical of research applications) such as sonic anemometers, hot-wire anemometers, single-turn thermocouples, etc. Sampling at these relatively high frequencies typically requires detailed knowledge of the instrument system from the sensors themselves through the logging and storage devices.

1 Hz - Most commonly used for cup anemometers and directional vanes. Note that 1 Hz sampling allows adequate variance measurements in these applications but still may exceed (higher frequency than) the time constants of common cup and vane anemometers. This sampling rate is sufficient to provide data for detailed meteorological analyses, but may not be necessary in a strictly operational environment.

0.1 Hz - Usually used for net radiometers, thermistors, and relative humidity sensors. Generally, the design and the data requirements from these sensors make higher frequency sampling unnecessary.

>.01 Hz - Most upper air measurements are done at lower frequencies. Pressure has typically been considered a low frequency measurement, though recent technological advances now allow higher frequency measurements when necessary.

5.3 Siting

Siting considerations are generally and instrumentation specific. The following section gives general measurement specific siting criteria.

Wind speed/Wind direction - The primary consideration in siting wind instruments is to sample the flow that will meet operational objectives. General siting guidelines are that obstacles will affect the flow for approximately 2 obstacle height (i.e. '2*H') upwind, 10 obstacle heights downwind and 2 obstacle heights upward. If the flow beyond the influence of obstacles is desired these criteria should be kept in mind. Many times, however, the flow in or near vegetation is of interest since vegetative surfaces are often the target in aerial application operations. Anemometers can be sited in canopies but dense or non-representative obstacles should be avoided, direct obstruction by obstacles such as branches is obviously unacceptable but may not be apparent until the canopy is disturbed at some higher wind speed. Instrument height is a difficult question to answer in generic terms. The wind will increase in velocity logarithmically with height above a solid surface. Since the change is greater near the surface, instrument spacing should be vertically smaller near the surface. However, in forest canopies vertical spacing is a difficult question. Generally, many tree species exhibit less dense foliage in the trunk space and a foliage maximum somewhere in the upper canopy. If resources exist, these layers should be monitored since they exhibit different flow characteristics. In an operational program, it might be useful to take one measurement in a free flow away from obstacles and another at an in-canopy height that corresponds to the in-canopy

target or ecological niche of the pest.

Temperature - Siting considerations for thermometry are similiar to those for anemometry with the important exceptions that thermometers have no moving parts, and they are susceptible to errors due to the thermodynamics of the instrument and the instrument mounting. Thermometers need to be shielded from direct solar radiation and isolated from surfaces or other heat sources which can conduct heat to the thermometer. It is general practice to collocate the thermometer with the wind instruments. Thermometers are often aspirated to avoid local heat build-up although it should be realized that the measured temperature is then an integration of the air volume being moved across the sensor.

Humidity - Humidity sensors should be sited in a representative location away from local moisture sources and shielded from solar radiation which can cause excessive drying through surface heating. Humidity sensors are also often aspirated to avoid local boundary layer effects on the sensor.

Radiometers - In most cases, radiometers are sited to obtain the maximum unobstructed view of the sky, although occasionally researchers position net radiometers in the canopy to measure the local energy budget. Since net radiometers view both upwards and downwards, it is important to site the net radiometer over a representative surface considering color, roughness and moisture.

Upper Air Measurements - Upper air measurements should be made so that they are representative of the source or of the atmosphere where drift is occurring.

Pressure - The exposure of a pressure sensor is generally not critical, although the pressure sensor should be kept in an environment where temperature does not vary excessively and where insects do not obstruct the pressure port. Pressure sensors must be calibrated occasionally in order to have useful accuracies. For most purposes, accuracies within 1 or 2 mb are sufficient.

6.0 FUTURE TECHNOLOGY CHANGES

It is difficult to predict the impact of future technological developments on the state of FS aerial spraying activities. However, there are some technologies which exist and would provide valuable information but for various reasons (typically cost and ease of use) are not yet used operationally in spray operations. The two primary areas which will be focused on here are:

1) Remote sensing technology which would allow more detailed information of meteorological parameters near the spray cloud as well as direct information regarding the cloud itself.

2) GPS technology which will allow more accurate positioning of all aspects of the spray operation.

6.1 Remote Sensing Technology

6.1.1 SoDAR

Sound Distance and Ranging (SoDAR) technology can be used to describe the wind field above the forest canopy in the vicinity of spray aircraft. This technology utilizes the temperature structure in the atmosphere to produce a sonic echo. The frequency of this echo is shifted proportional to the speed of the fluid producing the return. This instrumentation yields wind speed and direction information. Preliminary tests indicate that this is potentially very useful technology but standard commercial instrumentation does not yield data in the lowest levels (<30m) of the atmosphere of most interest in aerial spraying applications. This does not appear to be a fundamental limitation of the technique and the state of this technology is certainly worth monitoring. The SoDAR technology is becoming easier to use as time goes on but is still expensive (30-70K per unit). Although not yet available commercially, some organizations have built mini-sodars that are capable of good vertical resolution near the ground but with reduced height range. Such instruments typically reach heights of 100 to 200m with 10m resolution.

6.1.2 LiDAR

Light Distance and Ranging (LiDAR) technology can be used to describe the wind field at height and in monitoring of the actual position of spray material as it disperses after release. The LiDAR relies on light which is backscattered from atmospheric particulates. The motion of the scattering particles causes a frequency shift in the backscattered light which is proportional particle velocity. This

technology can also be used to perform direct tracking of the spray material as long as the material is at concentrations in the atmosphere which exceed background particulate levels. Other approaches using reflective tracers and chemical signatures may be possible to gather information on spray material at concentrations below that of background particulate.

There are a number of problems with the technology as it currently exists from an operational standpoint. The backscattered signal provides a qualitative picture of the spray material which provides relative information but is hard to quantify. The light beam is attenuated, in other words, if it is backscattered by a particle, no information can be gained about material behind that particle. Currently, this technology is both expensive (>60K) and it is not eye-safe, requiring operating and nearby personnel to wear safety goggles. This technology has substantial potential in aerial spray monitoring as these problems are solved.

6.1.3 GPS

Global Positioning Satellite systems (GPS) use signals transmitted from a constellation of polar orbiting Earth satellites to determine position on the surface of the Earth. The satellite constellation is owned by the U.S. Department of Defense (D.O.D.) and the satellite signal is systematically scrambled for national security reasons. However, this intentional accuracy degradation can be overcome by fixing the location of a point on the ground exactly. This point is then used to determine the degree and nature of the degradation and a decoded signal can be obtained. The positional accuracy available using this 'differential' signal is within 2m of actual position. This is approximately two orders of magnitude better than accuracies available with previous systems and positional updates can be obtained at high frequencies making the technology suitable for aircraft navigation.

This technology has many important applications to aerial spraying of pesticides. The most important application with regard to the modeling of spray drift is that the location of the source can be exactly determined as well as the positions of the monitoring stations. The concentration and depostion fields of the released material are very sensitive to source position, especially in the near field. This technology is now becoming more widely available, as the cost of GPS receivers comes down.

6.1.4 Other Remote Sensing Technologies

There are other technologies which are currently considered research tools but will impact the discipline by

improving the basic understanding of spray drift. Among these are sounders using various frequencies and modulation of radio waves. Perhaps the most important of these tools is the Radio Acoustic Sounding System (RASS). This is an important tool because it allows the remote sensing of temperature as well as wind speed and velocity. This temperature profiling capability would allow information to be gathered regarding atmospheric stability that would influence dispersion of the spray material. Other remote technology includes thermal infrared photography. This technique may prove useful for sensing spray material but is not yet widely used. It has the potential for wide spread use because it is relatively inexpensive. In general, this field is expanding rapidly as technology that was developed in defense programs is now being moved into the civilian sector.

7.0 Conclusions and Recommendations

This report has specified the meteorological measurements necessary to use the USDA Forest Service FSCBG complex of models (FSCBG, AGDISP and VALDRIFT) to simulate or predict spray drift. The report offers both the minimum monitoring requirements and suggestions for expanded programs which will improve model reality and, therefore, model accuracy. The report also endeavors to make readers aware of new meteorological monitoring technology which will impact understanding of spray drift in general and allow a more detailed understanding of future spray events. This new technology will feed back to future model development activities.

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Appendix E

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